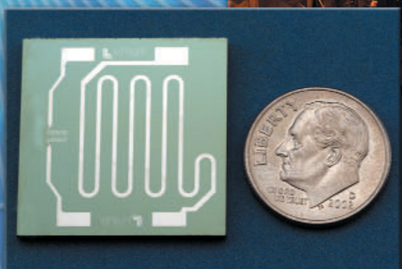
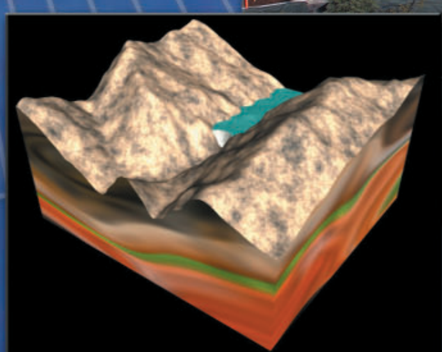
# 2001/2002 Engineering Annual Summary











University of California

Lawrence Livermore National Laboratory



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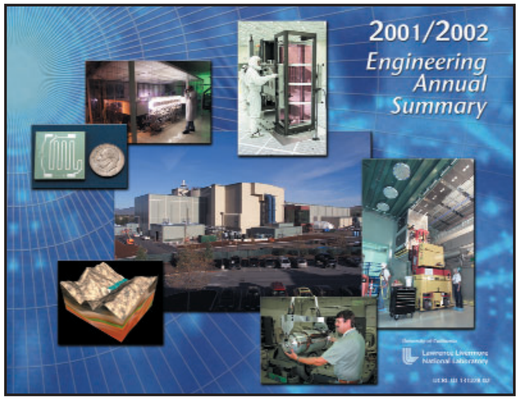


**About the cover:**
*Engineering plays a vital role in achieving milestones for programs and projects throughout the Laboratory. For the National Ignition Facility, or NIF (pictured at center), engineers developed advanced optics fabrication techniques, completed significant portions of the beampath infrastructure, and installed and commissioned control room hardware and software. Several stockpile stewardship projects recorded important advances, as did efforts in computer modeling, biohazard detection for homeland security, and microtechnology. Engineering personnel played key roles in all of these accomplishments.*

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# Contents

# Message from the Associate Director

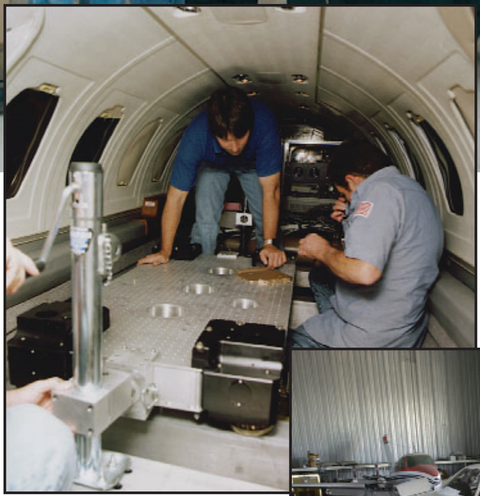
Changes in the international and national landscape brought on by both the September 11, 2001 attacks and a slowing economy have directly impacted LLNL and Engineering. The availability of our detectors for counter-terrorism immediately following September 11 reinforced our partnership with the Nonproliferation, Arms Control, & International Security (NAI) Directorate and our technology investment strategy, as well as renewed our pride in the Laboratory's national security mission. We are well-positioned to provide support to the newly-created Department of Homeland Security.

During both 2001 and 2002, Laboratory programs were growing at the same time that many high-quality people were seeking employment, and we hired a record number of employees into Engineering. The attrition rate among our engineering staff—which had risen alarmingly into double digits in 2000—has once again dropped closer to historical levels. Aggressive recruiting efforts at many of the nation's top engineering colleges and universities have paid off handsomely, and the quality of graduates seeking positions with the Laboratory has been outstanding. We will continue to seek out the best and brightest talent to meet the growing needs of the National Ignition Facility (NIF), defense, and national security.

Key leadership changes at the Laboratory and within Engineering have presented challenges. Former Associate Director Spiros Dimolitsas departed the Laboratory in November 2001 to assume a position at George Washington University. Glenn Mara, a senior manager for the NIF Program, was appointed Engineering's new leader in February 2002, but departed only a few months later when asked to serve as Laboratory Deputy Director for Operations by our new Laboratory Director, Michael Anastasio. I am gratified to report that despite these senior leadership changes, Engineering has continued to execute on its commitments to the programs thanks largely to the dedication and focus of our employees.

On the lighter side, the Laboratory celebrated its 50th anniversary in 2002, and we took the opportunity to remember Engineering's history and recognize the accomplishments of our people. We produced a handsome book, *History & Reflections of Engineering at Lawrence Livermore National Laboratory*, and an award-winning documentary video, "A Journey Through Time: 50 Years of Engineering at LLNL." Numerous retrospective lectures and presentations were given, and activities were capped in September by Celebration Week. We were treated to a series of addresses by visiting dignitaries, and we enjoyed sharing memories with Engineering alumni at our annual picnic.

Engineering personnel received significant recognition over the last two years from professional societies, universities, the government, and technical organizations. In 2002, we were key contributors on four of the Laboratory's five teams that received prestigious R&D 100 Awards—indicative of the multidisciplinary spirit of Engineering and the Laboratory. Engineering personnel were awarded 29 patents in 2001 and 26 in 2002, bringing our total to well over 1000. Our Leadership Development Program and Project Management Initiative continue to attract emerging leaders and prepare them to assume responsibilities for managing people and projects.



In summary, during these last two years we have been touched by tragedy, but our resolve and commitment to our national security responsibilities has been strengthened. We have been challenged by transitions in leadership, but we have held to our commitments. I trust that as you review the accomplishments of the last two years documented in this report, you will see the embodiment of Engineering's core values: Innovation, Quality, Integrity, Teamwork, Respect, and Safety.

***Left page:*** *Aerial view of the devastation at Ground Zero in New York City.*

***Left page, inset:*** *Jens Mahler, acting Associate Director for Engineering.*

***Right page:*** *Pictured are some of the 34 Engineering employees who were part of the LLNL teams that aided in the rescue efforts of the September 11, 2001 New York terrorist attacks. Some teams used advanced sensors to locate possible live victims, others used remote aircraft to look for hazardous airborne plumes to assure the safety of workers cleaning up the World Trade Center, and others put sensor systems around key U.S. areas and facilities to protect against possible additional terrorist attacks.*

***Right page, insets:*** *The Hyperspectral Infrared Imaging Spectrometer (HIRIS), a remote sensing system for standoff detection of gases, is installed by Engineering personnel in an aircraft at the Livermore, CA airport. The airborne system was outfitted and in place collecting data above Ground Zero only one week after deployment was requested.*

# Profile of Engineering

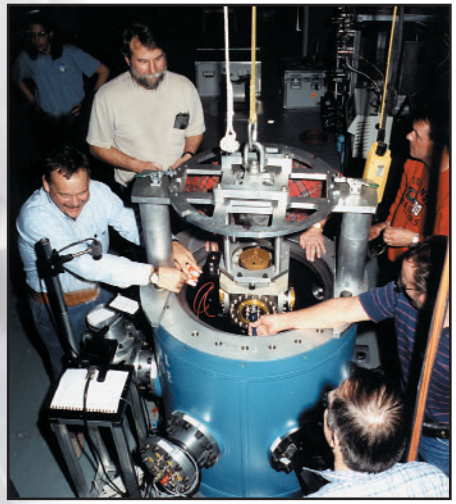
## Mission

Engineering's mission is twofold: to translate scientific ideas into actual products, and to ensure the long-term vitality of the Laboratory through an Engineering organization that anticipates future program needs for an engineering workforce, engineering standards, engineering technologies, and engineering facilities.

Although we are but one of 13 Laboratory Directorates, Engineering includes about one-quarter of the Laboratory's population. Eighty percent of Engineering employees are matrixed to (that is, have work assignments in) a wide range of Laboratory programs. Therefore, our organization plays a unique role in providing not only engineering standards for the Laboratory, but also a degree of continuity and stability.

### *Engineering's hallmarks include:*

- Designing and building complex instruments and machines ready for production, such as diagnostics for mounting on missile test flights, portable sensors for detecting chemical and biological agents in the field, or weapons for the United States' nuclear stockpile.



- Designing and helping construct most of the Laboratory's unique test facilities, such as those where weapons are environment- and/or performance-tested and facilities where new manufacturing processes are developed.

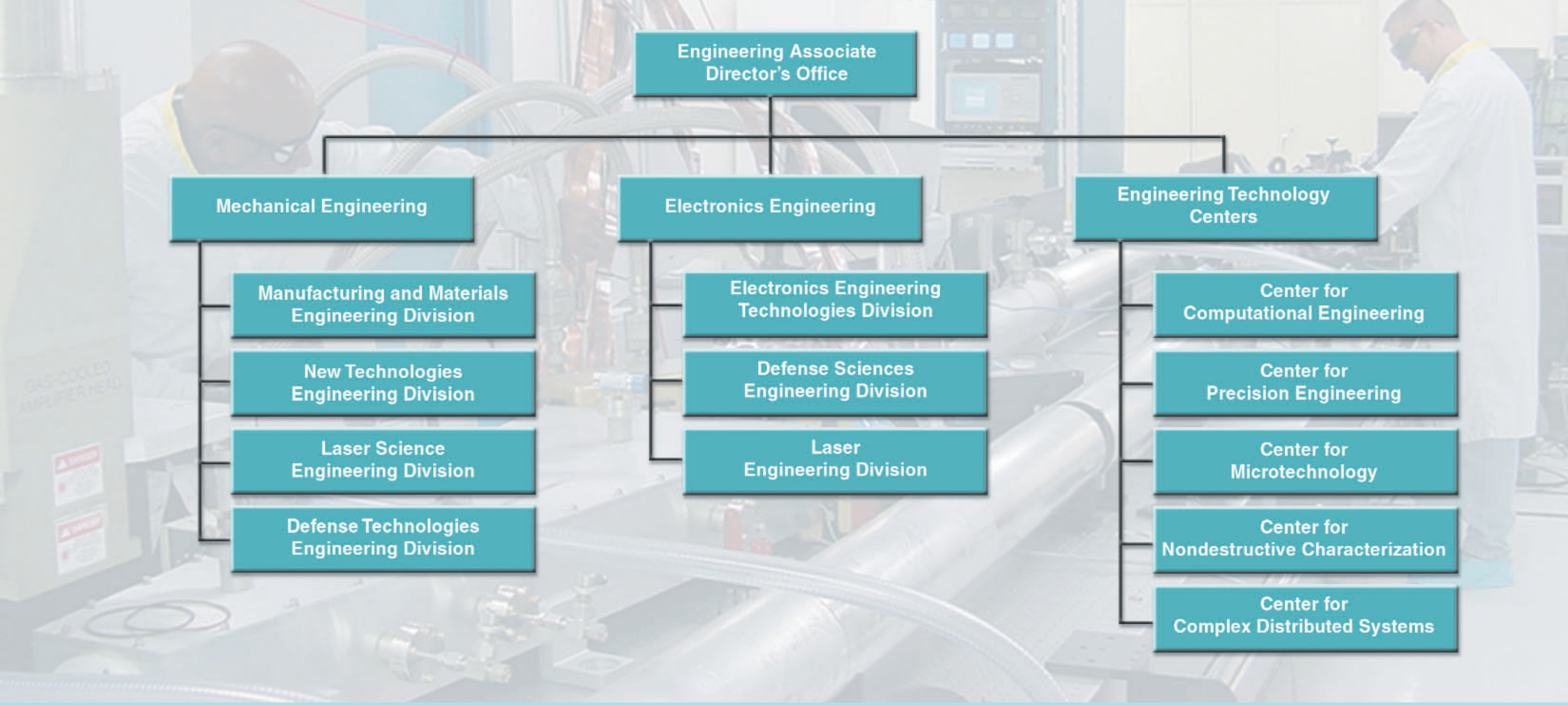
- Conducting research in advanced, broad-application technologies that enhance the Laboratory's ability to pursue its mission.

A profile of Engineering at LLNL can best be given in terms of three categories: our workforce, our technology areas of expertise, and the capabilities in our facilities and infrastructure.

## Organization

The Engineering Directorate is organized into four Mechanical Engineering divisions, three Electronics Engineering divisions, and five Technology Centers. Working together, these divisions and centers form an Engineering organization that regularly takes on challenges to accomplish what would seem to be impossible.

Our current staff of over 2200 has expertise in mechanical, electrical/electronics, computer, nuclear, chemical, materials, civil, and other types of engineering. For customers inside and outside the Laboratory, Engineering personnel manage numerous large and small projects requiring complex interactions and a multidisciplinary approach. Engineering personnel simulate engineering systems, design engineering systems, and test systems performance.




## Technology core competencies

We undertake projects with high technical risk, integrate and extend technologies concurrently, and use the extremes of both ultrascale and microscale to achieve results. We call this "Xtreme Engineering." Such projects might include building massive structures but aligning them with extremely fine precision.

For example, Engineering employees are currently involved in building the National Ignition Facility (NIF), a stadium-size laser facility with more precision optics than all the world's telescopes combined, and which incorporates 5100 tons of steel structures aligned at one-hundredth-of-an-inch precision.

***Left page:*** *High-speed radiographic images of implosions are taken with the powerful Flash X-Ray machine, or FXR, located at Site 300.*

***Left page, inset:*** *Engineering personnel originated the idea of conducting high-explosive shock experiments in disposable steel vessels such as this one, which significantly reduced project costs and experiment turnaround time.*

***Right page:*** *Engineering is organized into the Mechanical Engineering department, consisting of four divisions; Electronics Engineering department, consisting of three divisions; and five Technology Centers.*

***Right page, inset:*** *A view looking down the length of one of the laser bays in the National Ignition Facility.*

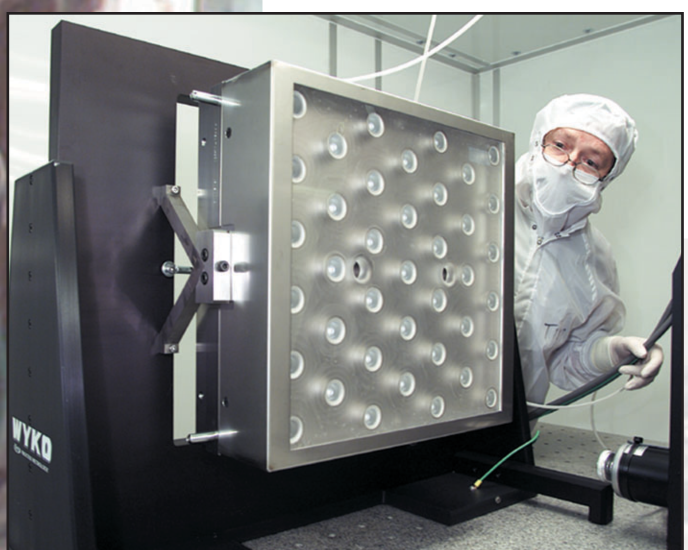
## Engineering's core competencies

### Integrated engineering of large, complex, applied physics systems

- Nuclear and advanced conventional weapons engineering
- Nuclear materials disposition
- Laser systems engineering
- Isotope separator engineering
- Safety-critical control systems
- Accelerator and particle detector systems engineering
- Field engineering
- Security control systems
- Adaptive optics
- Electronic commerce and concurrent engineering systems

### Large, complex computation modeling and simulation

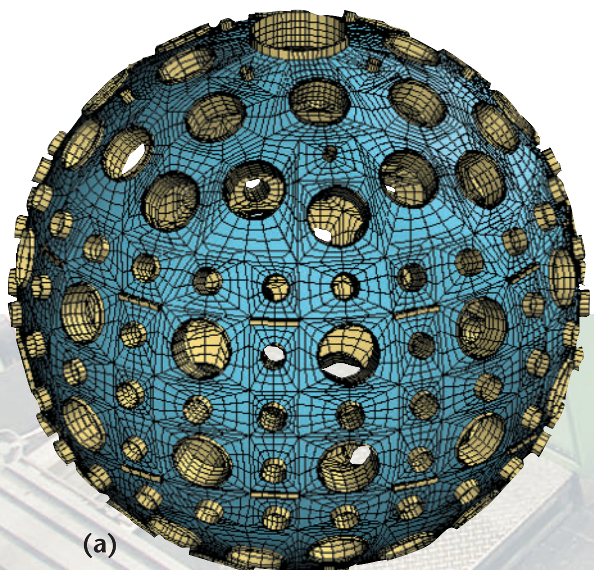
- Structural, thermal, and fluid system analysis and design
- Nonlinear systems modeling
- Biological systems modeling
- Accelerator and microwave electronics analysis and design
- Antenna modeling
- Nuclear and electromagnetic radiation effects
- Integrated photonics
- Information systems vulnerability analysis and operations
- Transportation vehicles, systems, and infrastructure
- Natural hazards assessment and mitigation



# and activity areas are:

## *Microscale engineering*

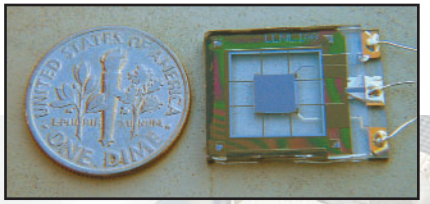
- Precision, brittle material fabrication
- High-precision optics
- High-precision diagnostic instruments
- Miniaturized, integrated analytical biological and chemical systems
- Medical microinstruments and microtools
- Genome sequencing instrumentation
- Optoelectronic communication devices



(a)

## *Measurement science at extreme dimensionalities*

- Real-time data acquisition and processing
- Transient diagnostics
- Remote characterization and detection systems
- Ultralow-power, precision proximity radar
- Adaptive sensors and networks
- Nondestructive evaluation
- Accelerated materials aging
- Biomedical imaging
- Geologic signal processing and analysis
- Subsurface (including underground) imaging
- Environmental monitoring and characterization

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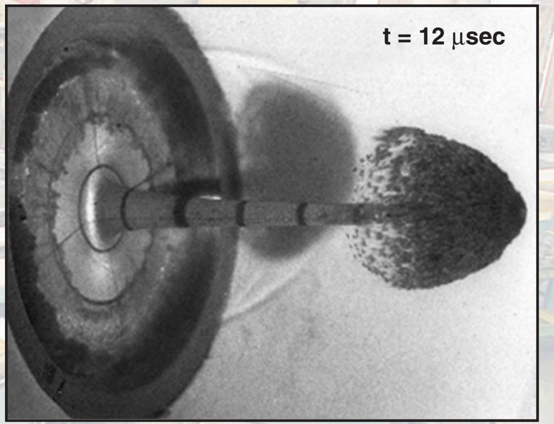



(c)

***Left page:*** *A modular, telephone-booth-sized line replaceable unit, or LRU, is installed into a NIF beamline.*

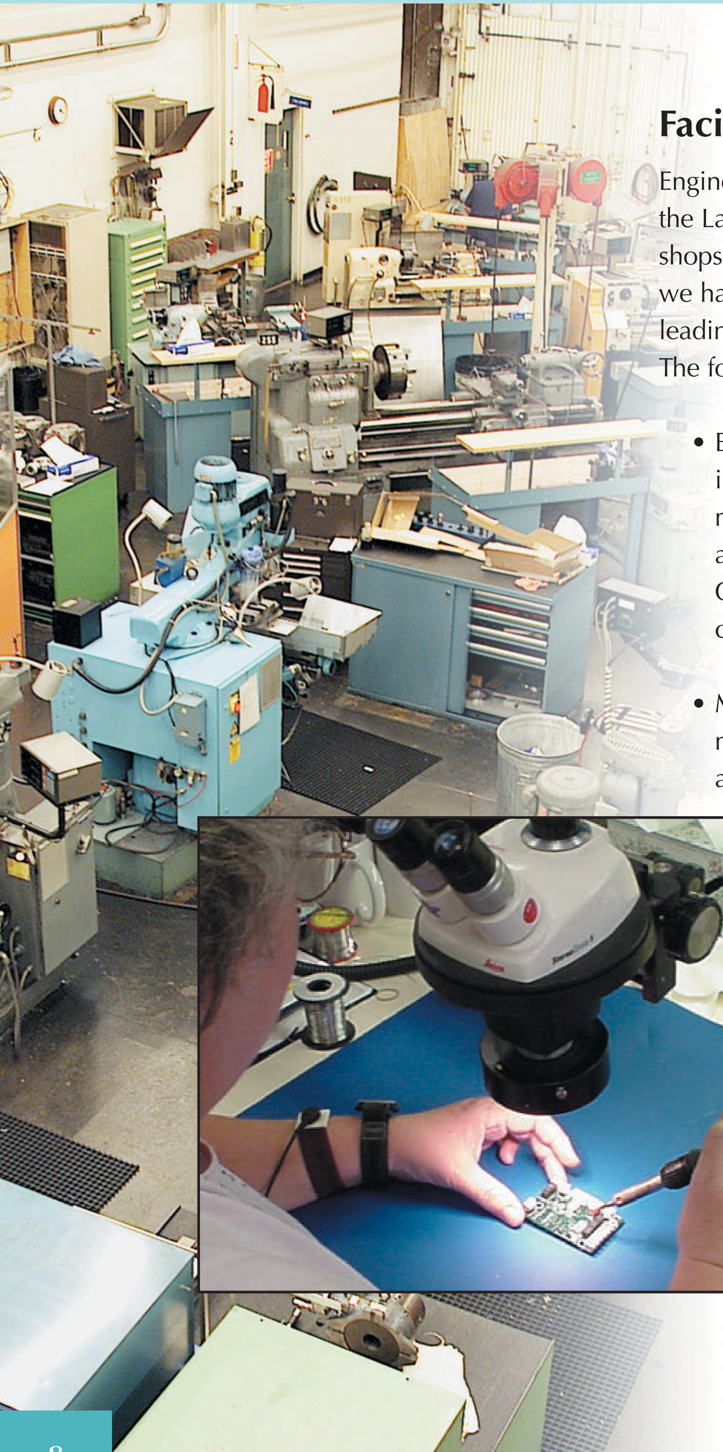
***Left page, inset:*** *Deformable mirrors such as this one, used to correct aberrations in the NIF laser beamlines, must be fabricated and tested in a clean environment.*

***Right page, inset (a):*** *The NIF target chamber was modeled using LLNL's NIKE3D and TOPAZ3D codes.*

***Right page, inset (b):*** *Research into ever smaller sensors with lower power requirements led to the development of this wireless micro-accelerometer, which measures only 15 milli-meters square and 3 millimeters thick (pictured next to a dime for size comparison).*

***Right page, inset (c):*** *Engineering often needs to model the behavior of materials at high pres-sures and strain rates, such as the jet captured in this high-speed photo of a shape charge.*

# Profile of Engineering



## Facilities and special capabilities

Engineering owns and manages a number of facilities at the Laboratory, including engineering laboratories and shops as well as office buildings. Within these facilities, we have developed special capabilities that produce leading-edge results and advance our technical expertise. The following are only a few of the highlights.

- Engineering's mechanical fabrication facility includes a range of activities from metals machining to refined optical/glass techniques and laser processing. Other services include CAD/CAM design, metallographic analysis, and custom machine-tool development.

- Materials evaluation efforts include the study of mechanical response of materials, components, and assemblies under various conditions of load, deformation, temperature, and environment.

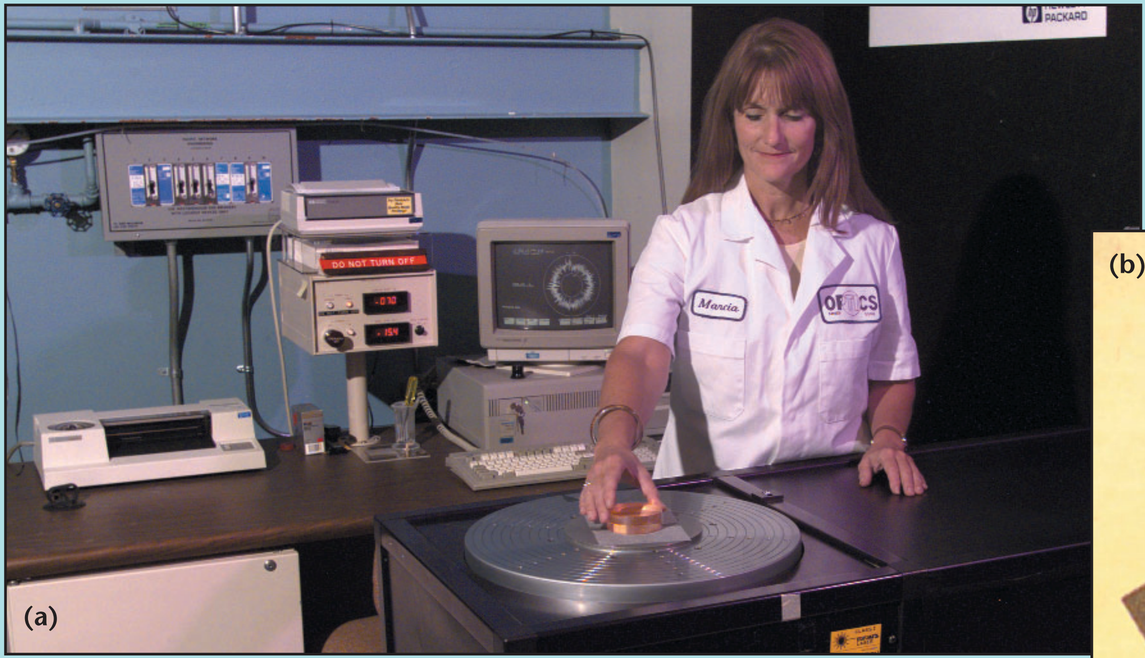
- We employ nondestructive evaluation capabilities ranging from ultrasonic inspection and characterization to infrared and emissivity imaging in 3-D.

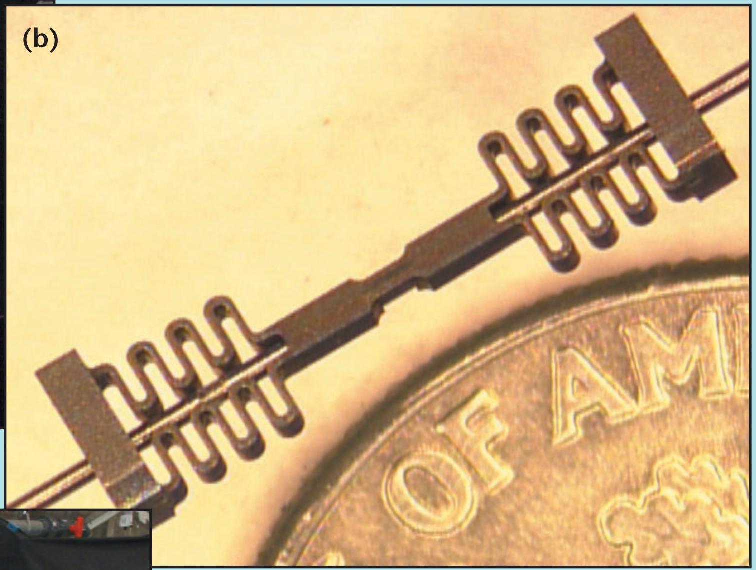
- Our electronics manufacturing facilities (which are ISO 9001:2000 quality certified) include central drafting, electronic fabrication/packaging, printed circuit board/surface mount technology, and the through-hole technology facility.

- Our microtechnology building houses 3500 square feet of Class 10–1000 clean rooms for micromachining, silicon microelectronics, III–V semiconductor optoelectronics, and guided-wave photonics. Other labs provide material characterization and device-testing capabilities, microscopic inspection, packaging, and electrical and optical testing of devices.

- Our high-pressure lab is one of the most complete high-pressure design, fabrication, and testing facilities in the world.

- Our abilities in plasma and high-power systems allow us to design, construct, and test total systems, including the necessary support circuits, subsystems, and software.





***Left page:*** *Overhead view of Engineering's main bay machining facility, which provides a broad range of machining capabilities including computer numerically controlled (CNC) milling of large parts.*

***Left page, inset:*** *Electronics manufacturing capabilities include fabrication and assembly of special-application printed circuit and printed wiring boards.*

***Right page, inset (a):*** *A technician sets up the optical heterodyne profilometer, a noncontact surface roughness profiler with a height sensitivity of one-tenth of a nanometer.*

***Right page, inset (b):*** *Engineering's precision machining facility provides miniature machining capabilities using a wide range of materials—from plastics to exotic metals.*

***Right page, inset (c):*** *Precision engineering team members pose with a prototype of a potassium dihydrogen phosphate (KDP) crystal finishing machine, developed at LLNL to produce high-quality optics for use in NIF.*

## *Engineering expertise in analysis, simulation, and testing supports the W80 Life Extension Program*

*We have developed 2-D and 3-D thermal and structural models of the overall W80 system, and are performing numerous analyses of the system, its subsystems, and components.*

The Laboratory is a key participant in the Stockpile Stewardship Program, which ensures the safety, security, and reliability of the nation's nuclear deterrent without nuclear testing. It is our responsibility to test and analyze the weapons in the enduring stockpile so that we can certify to the National Nuclear Security Agency (NNSA) that they will perform as intended.

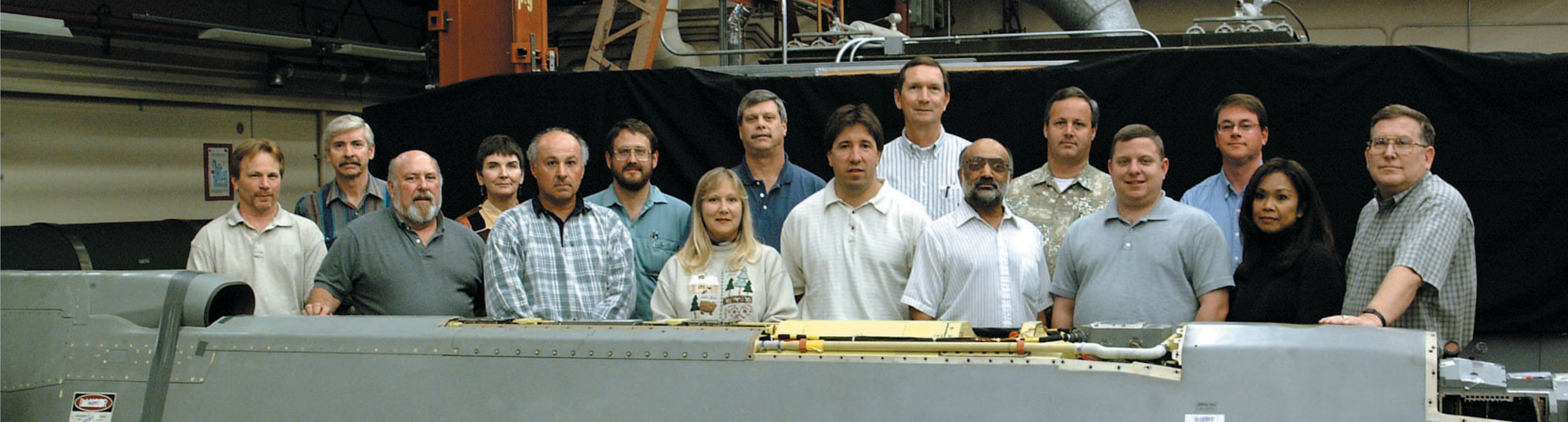

(a)

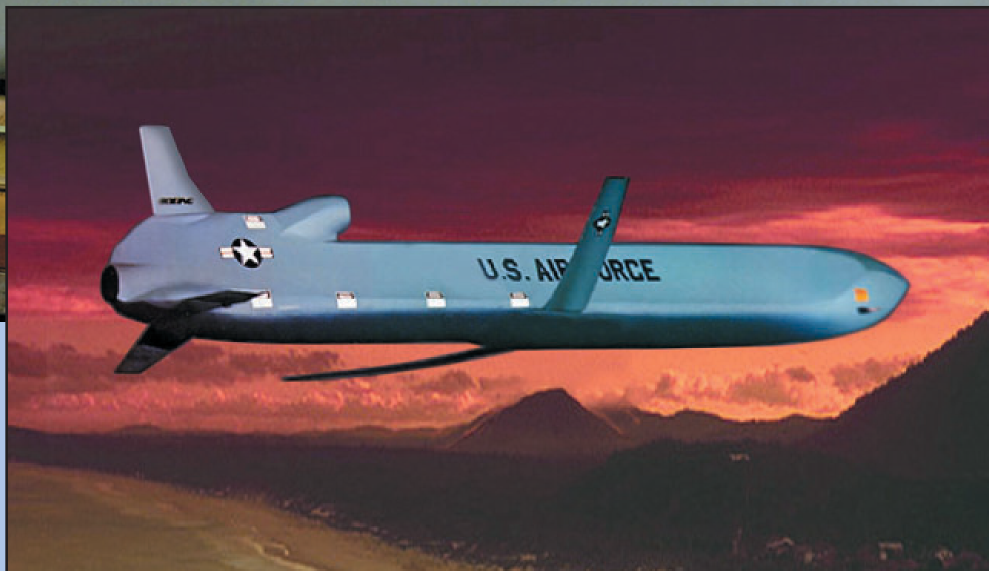

(b)

The W80 nuclear weapon system was deployed in the early 1980s in conjunction with the Navy's Tomahawk cruise missile and the Air Force's Air Launched Cruise Missile (ALCM) and Advanced Cruise Missile (ACM). Near the end of its designed life cycle in the late 1990s, plans were made to extend the life of the W80 system for another 20 years. The NNSA determined that LLNL would be responsible for the life extension program for future variants of the W80.

The life extension process is fundamentally the same as that used to design a new weapon system. We have assembled a multidisciplinary team of engineers, physicists, chemists, and materials scientists to: 1) develop a baseline understanding of the existing system, 2) modify the system to extend its life, and 3) quantify the system margins and uncertainties and certify that the system continues to meet specified requirements.

Starting in FY01, we conducted hydrodynamic tests to provide data to validate our physics analytical models. Unlike past similar activities, extensive analysis has been performed at the beginning of the life extension process. We have developed 2-D and 3-D thermal and structural models of the overall W80 system, and are performing numerous analyses of the system, its subsystems, and components. We are currently conducting full system engineering tests to evaluate the ability of the system to survive the thermal, shock, and vibration environments that a warhead might be subjected to during its lifetime. We will also be conducting flight testing to measure the thermo-mechanical environments. Thermo-mechanical testing to measure any temperature-induced strains, gaps, or displacements of components is being performed to characterize the physical configur-ation and loads within the W80 system.






In 2003, we will begin captive-carry flight test preparations to provide information on the environments experienced by the W80 warhead when the ALCM and ACM missiles are mounted on the B52 aircraft. These tests, to be performed on both the existing and new designs, will measure temperatures, vibration, and other environmental conditions. Flight tests of the new design are scheduled to follow in 2004.

***Left page:*** *A pod of cruise missiles is shown slung under the wing of a B52 bomber.*

***Left page, inset (a):*** *The W80 nuclear weapon system is deployed in the Navy TLAM cruise missile (shown leaving the water) and the Air Force's ACM (in black) and ALCM (red, white, and blue) cruise missiles.*

***Left page, inset (b):*** *A test technician prepares a W80 test unit for vibration, shock, and thermal environment testing.*

***Right page:*** *Some members of the W80 Life Extension Program team are pictured next to an Air Force ALCM cruise missile.*

***Right page, inset:*** *The Air Force ALCM, carrier for the W80 Mod 1 nuclear warhead.*

## *New Contained Firing Facility provides unique high-explosives testing capabilities*

*Engineering personnel were intimately involved with CFF construction design and oversight over the last two years.*

The Laboratory's new Contained Firing Facility (CFF)—the largest explosives chamber in the world—was dedicated at Site 300 in August 2001 and began providing indoor testing of high explosives in February 2002. Housing the Laboratory's most modern hydrodynamic testing capabilities, the CFF is an important adjunct to Livermore's science-based Stockpile Stewardship Program. Livermore scientists must assure the safety and reliability of our nation's nuclear stockpile as weapons age beyond their originally planned life, but without the validation that in the past was provided by underground nuclear tests. Computer modeling supplies a wealth of information about how the explosives and assemblies in nuclear weapons will behave, but hydrodynamic testing of certain components is necessary to validate the computations. The CFF was constructed to help satisfy this mission.


(a)


(b)

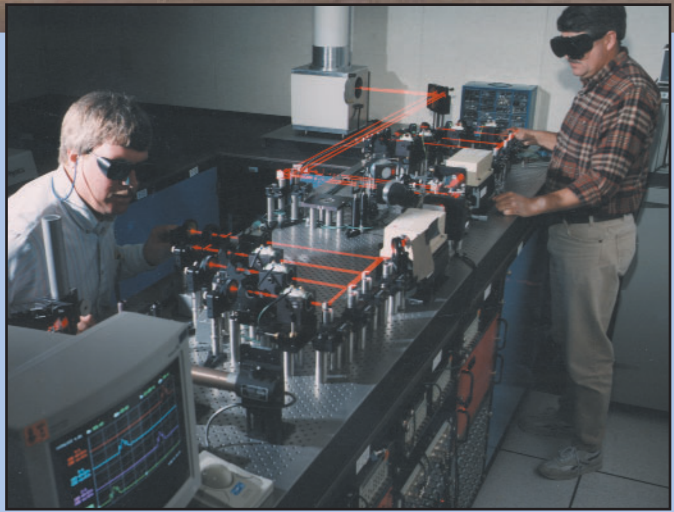
Engineering personnel were intimately involved with CFF construction design and oversight over the last two years. They provided program requirements to facility contractor Parsons Architectural and Engineering, interfaced with and oversaw the design, construction, and activation of the building's systems, and were part of the team that granted final approval of the construction and formal acceptance of the building for B Program.

In addition to the CFF construction, the existing experiment firing and diagnostic control systems were completely rebuilt. Engineering team members developed all requirements, hired internal resources, and contracted with an external firm to provide engineers and programmers to design and implement these control systems. Additionally, engineers designed and implemented a new control system for the 18-megaelectron-volt Flash X-Ray machine, which is collocated with the CFF.

The CFF contains a variety of other advanced, high-speed optical, electronic diagnostic, and support equipment that together constitute a unique capability to test the behavior of high-explosives-driven assemblies. Engineers used their expertise to build diagnostic feed-through ports (including fiber optic and glass optic feed-though ports); experiment auxiliary systems in the chamber, such as

industrial gases (nitrogen, methane, helium, and compressed air); interlocked utility power; experiment heating and cooling systems; and chamber cleaning systems. General systems debugging was performed, and improvements were made to the chamber heating, ventilation, and air conditioning and wash water systems.

With the CFF now operational, hydrodynamic testing associated with the W80 weapon life extension program and other high-explosives testing is well under way.



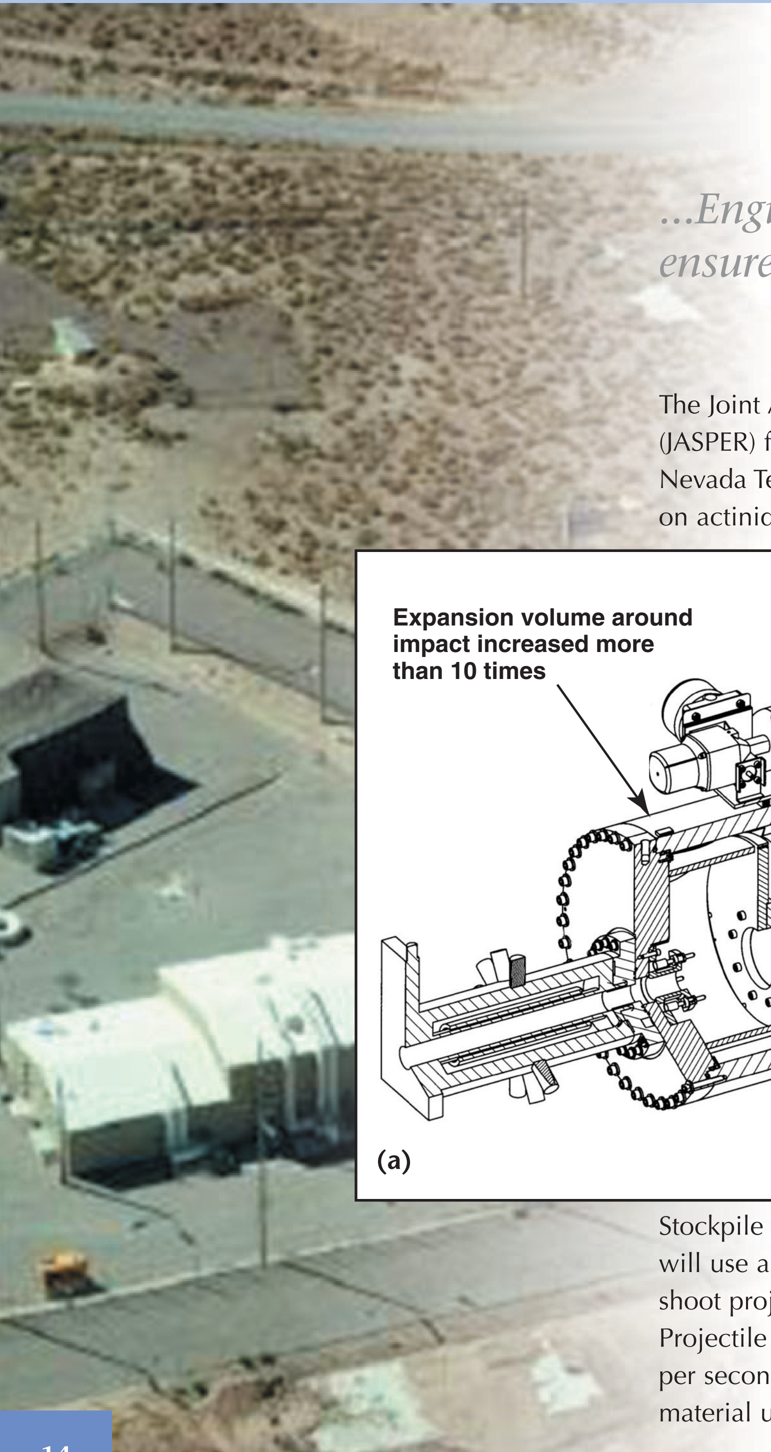
***Left page:*** *Interior of the CFF chamber, showing the Flash X-Ray (FXR) bullnose illuminated in red.*

***Left page, inset (a):*** *One of four Fabry-Perot velocimeters, to be installed in the CFF in 2003. These instruments will allow simultaneous measurements of up to 20 different spots in a single experiment.*

***Left page, inset (b):*** *The CFF control room contains control systems for diagnostics, experiment firing, and chamber systems.*

***Right page:*** *The CFF facility at Site 300, showing structures housing the chamber ventilation systems, air scrubbers and filters, and exhaust stack.*

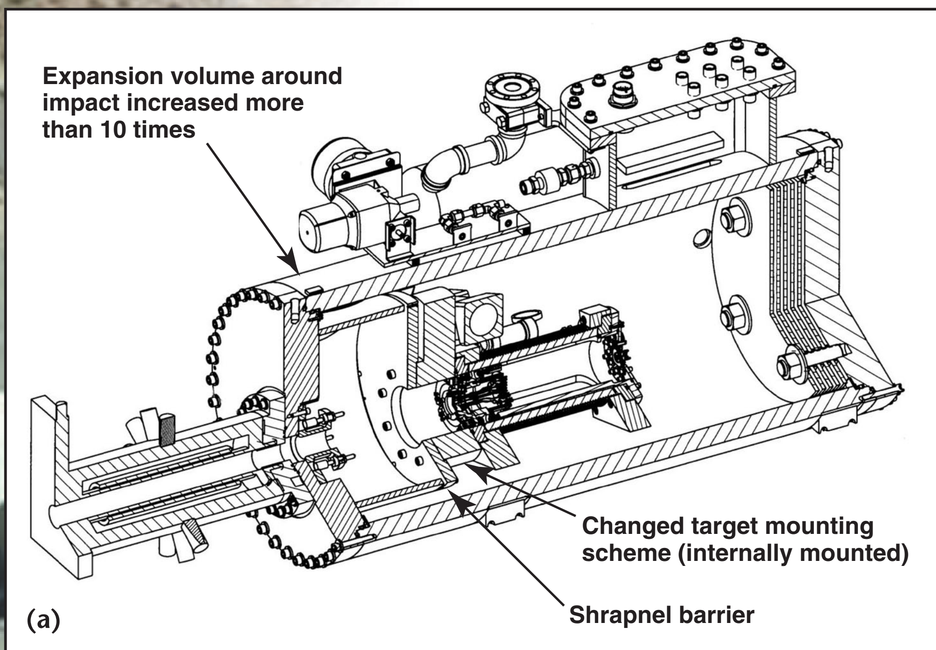
***Right page, inset:*** *A ruby laser illumination system mated with an electronic camera such as this one will be installed in the CFF in 2004.*



## *Significant design, testing, and validation challenges were overcome by JASPER engineers*

*...Engineering activities in 2001 and 2002 involved rigorous testing to ensure safe and reliable operation.*

The Joint Actinide Shock Physics Experimental Research (JASPER) facility is being developed at the Laboratory's Nevada Test Site to conduct shock physics experiments on actinides and other hazardous materials. Part of the Stockpile Stewardship Program, JASPER will use a two-stage, light-gas gun to shoot projectiles at actinide targets. Projectile velocities will range from 2 to 8 kilometers per second, enough to induce pressures in the target material up to 6 megabars, or several million times atmospheric pressure. Such extreme laboratory conditions will approximate those experienced in nuclear weapons, and data from the experiments will be used to determine material equations of state and to validate computer models of material response for weapons applications. Part of a suite of above-ground experimental facilities, LLNL is partnering with Los Alamos National Laboratory, Sandia National Laboratories, and Bechtel Nevada on the JASPER project. LLNL and Engineering have had lead roles in all aspects, including technical direction and management of design, startup, and operation of the JASPER facility and program.

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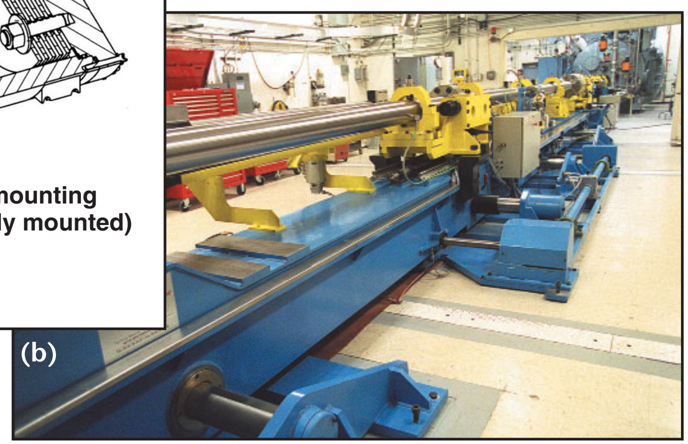
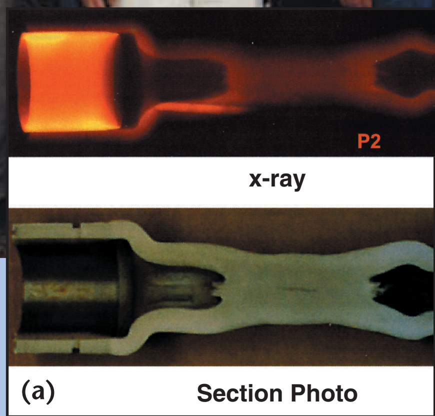
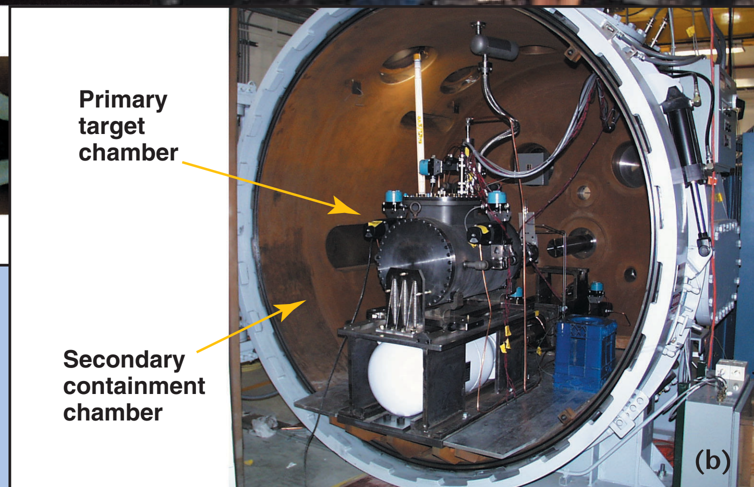


(b)

With facility construction, installation of the gas gun, and initial system integration demonstrations completed by the end of 2000, Engineering activities in 2001 and 2002 involved rigorous testing to ensure safe and reliable operation. This included verification testing, including firing the gas gun in its operational




configuration using surrogate-material targets, and facility validation and authorization. Gas gun performance and diagnostics have been validated, and quality of the data is comparable to an existing, similar system housed at the Laboratory's Livermore site.

Some initial system testing revealed concerns with design of the primary target chamber. However, a new design was successfully brought on-line and tested for containment. A thorough testing program, defined early in the project, was sufficient to catch the issues, and the JASPER team now has a process ready to certify new target chamber designs as they are needed for future experiments.

Significant engineering development effort was also dedicated to an explosively-driven ultrafast closure valve system. As the first line of defense against contamination, it was considered early in the project to be one of the biggest concerns. Engineering personnel worked closely with the manufacturer to assure the valve would function reliably. Thanks to this successful cooperative effort, the valve has exceeded expectations during start-up tests.

With full facility certification and operation expected in 2003, JASPER will be a key component in fulfilling scientific and programmatic needs for a national shock compression facility, providing important physics data necessary to meet Department of Energy requirements.

***Left page:*** *The JASPER facility is located at the Laboratory's Nevada Test Site.*

***Left page, inset (a):*** *A cutaway illustration of the redesigned JASPER primary target chamber.*

***Left page, inset (b):*** *The JASPER two-stage gas gun, showing the launch tube through which projectiles are fired at velocities up to 8 kilometers per second. In the background is the secondary containment chamber.*

***Right page:*** *The JASPER start-up team comprised engineers, scientists, technicians, and support personnel from LLNL, the National Nuclear Security Administration, and Bechtel Nevada.*

***Right page, inset:* (a)** *The ultrafast closure valve system completely seals the entrance to the primary target chamber microseconds after the projectile impacts the target material.*

***Right page, inset (b):*** *JASPER's primary target chamber houses the target material, and the high-explosive ultrafast closure valve traps radioactive contaminants within the chamber after the projectile enters. A secondary containment chamber assures that if any materials escape from the primary target chamber, they will not migrate into the building environment.*

## *Engineering enables "Team NIF" to meet milestones*

*Both Mechanical and Electronics Engineering have played key roles in the development of design requirements, fabrication and procurement of specialized parts, clean assembly and installation of components, and commissioning of all [NIF] components and systems.*

Engineering contributions to the National Ignition Facility (NIF), the 192-beam laser experimental facility under construction since 1997, have been indispensable and vital to the success of the project. With the completion of the conventional facility in September of 2001 and the activation of the first four laser beams in late 2002, the NIF Team has been moving rapidly toward the NIF Early Light (NEL) goal of four ultraviolet beams directed to the center of the 10-meter-diameter target chamber planned for spring of 2003.


NIF will use the world's largest laser to compress and heat small targets to extreme temperatures and densities approaching those in the sun or in an exploding nuclear weapon. NIF will also drive BB-sized capsules of fusion fuel to thermonuclear ignition. Such experiments will help scientists sustain confidence in the nuclear weapon stockpile without nuclear tests, as part of the National Nuclear Security Administration's Stockpile Stewardship Program, and produce additional benefits in basic science and fusion energy. NIF is 704 feet long, 403 feet wide, and 85 feet tall—about the size of a football stadium—and consists of three connected buildings: the Optics Assembly Building, the Laser Building, and the Target Area Building.

Hundreds of Engineering Directorate personnel, including engineers, designers, coordinators, and technicians have contributed to all of the achievements and milestones described below. Both Mechanical and Electronics Engineering have played key roles in the development of design requirements, fabrication and procurement of specialized parts, clean assembly and installation of components, and commissioning of all components and systems.

On October 23, 2001, the Cluster 3 beampath (6 bundles of 8 beams each) was completed in Laser Bay 2 by a team of NIF Project and Engineering personnel, union building trade crews, and other subcontractors from the installation contractor, Jacobs Facilities, Inc. The Cluster 3 beampath consists of the enclosures and supports for 48 of NIF's beams, including the main and power amplifiers, cavity and transport spatial filter systems, the injection

laser system, the periscope assembly, which includes the optical switch used for NIF's unique multi-pass amplifier architecture, and the deformable mirror system at the end of the main amplifier cavity section. These beampath components have stringent alignment and cleanliness requirements to satisfy operational criteria for the optical systems installed inside.

At the end of October 2002, the first infrared laser light was generated in the NIF Master Oscillator Room, which provides the pulses of light to NIF's 48 preamplifier modules for injection into the main laser system. In late 2001 and early 2002, the NIF control and laser diagnostics systems were installed, tested, and commissioned.

Installation of the first Power Conditioning System (PCS) modules began in February 2002. The capacitors in the PCS store about 350 megajoules of electrical energy, which is delivered to the 8000 flashlamps in NIF. On June 18, the first main amplifier flashlamps were successfully fired within Bundle 31, which contains the first four laser beams to be commissioned.

NIF's optics and optomechanical systems are modular components called Line Replaceable Units, or LRUs, which are installed in the beampath to inject, amplify, condition, or transport the laser beam to the target chamber. By October 2002, nearly 130 LRUs needed for NIF's first light milestone were installed to NIF's precision

***Left page:*** *Construction work in progress in Laser Bay 2.*

***Left page, inset:*** *Completed installation of the first cluster (48 beams) of the beampath infrastructure (Laser Bay 2, Cluster 3).*

***Right page:*** *Another view of the completion of the Laser Bay 2 beampath infrastructure.*

# 2001/2002 Accomplishments: NIF Beampath Infrastructure

cleanliness and alignment standards and ready for commissioning. LRU installation accomplishments are described in another portion of this report.

Beginning in late 2002, a series of increasing energy laser shots culminated in the generation of 43 kilojoules of infrared laser light in four beams directed into a diagnostics system located in Switchyard 2.

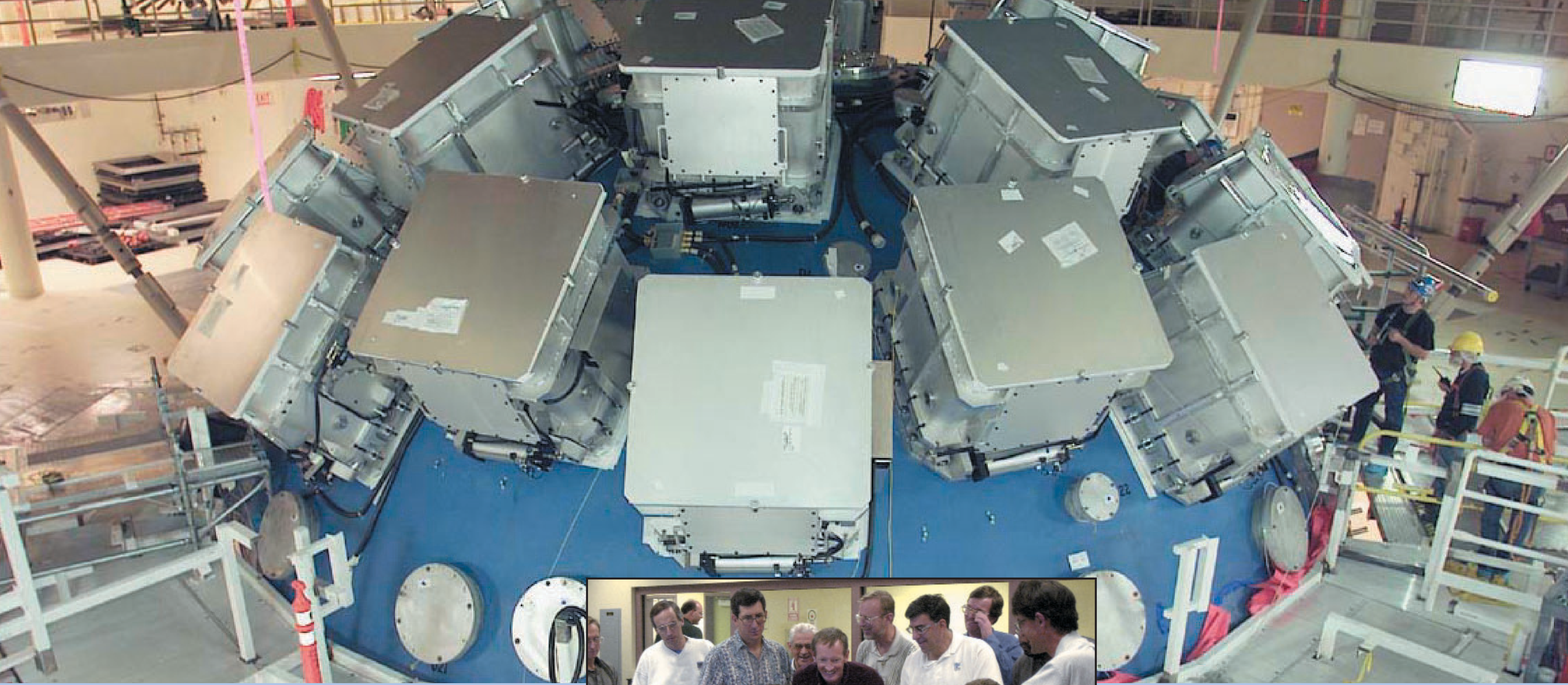
At the same time, utilities were also being installed, including over 100 miles of high-voltage cable required to carry the energy from the PCS modules to the laser amplifier flashlamps. Amplifier cooling systems for the main amplifier were completed in May, while Cluster 3 piping and electrical utilities were finished later in 2002. These utility systems were installed in partnership with the mechanical contractor, Kinetics Systems, Inc., and the electrical contractor, Contra Costa Electric.

Through the summer of 2002, the Clusters 3 and 4 beampath components and support steel in Switchyard 2 were installed. These components included the Roving Mirror Diagnostics Enclosure (RMDE), which is a special diagnostic system for evaluating laser beam performance, stainless steel beam enclosures, and elbow enclosures to support turning mirror LRUs.

The first test shots in NIF—called “rod shots”—began on October 15, 2002. Using all the main laser LRU systems and controls except the main amplifiers, light was successfully propagated all the way from the Master Oscillator Room through the preamplifier modules, the injection laser system, and the main laser beampath to the Switchyard 2 diagnostic calorimeters located in the RMDE.

Two months later, the first main laser system shot was fired in Laser Bay 2, which integrated operation of the beampath and its supporting utilities using all the Bundle 31 laser components and optics, power conditioning system, diagnostics, and computer control system. On December 11, a 13.4-kilojoule shot was fired with less than 1 percent variation among the four beams and an excellent energy balance, easily meeting the first NEL milestone requiring 10 kilojoules of laser energy. On December 17, the NIF Team successfully fired 43 kilojoules into the RMDE.

In preparation for first light to the target chamber in early 2003, a precision diagnostic system, which was used during the Beamlet prototype test program, is currently being installed and commissioned in Switchyard 2. The Final Optics Assembly (FOA) for the bottom “quad” of Bundle 31 was also installed on the target chamber. The FOAs house the special crystals and optics that convert the infrared laser light to ultraviolet light and focus it on the target at the center of the target chamber. Within the target area, the target positioner, target alignment sensor positioner, and other target experimental diagnostic packages are being installed on the chamber and commissioned. With all these systems installed and commissioned, NIF is planning to achieve its next NEL milestone




of 4 kilojoules of ultraviolet laser light at the center of the target chamber in spring 2003.

To meet all of these milestones, Engineering personnel have provided leadership and technical excellence to the NIF Project. Engineering teams have worked seamlessly in integrated multi-Directorate teams to provide the highest quality products in a safe and cost-effective manner. Engineering remains focused on contributing to the creation of this world-class experimental facility for national security, energy security, and basic science needs and is proud to be a part of "Team NIF."

***Left page:*** *A technician checks the operation of the roving calorimeter diagnostics assembly in the Roving Mirror Diagnostic Enclosure.*

***Left page, inset:*** *Automated Guided Vehicle installing transport spatial filter lens LRUs.*

***Right page:*** *Final Optics Assemblies installed on the upper hemisphere of the target chamber.*

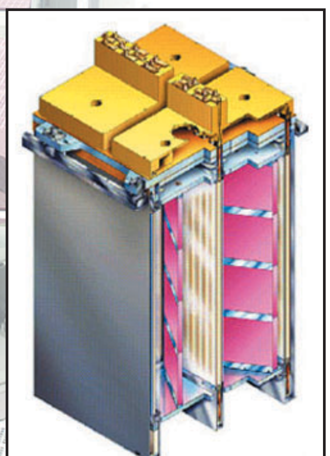
***Right page, inset:*** *NIF team members express their enthusiasm after a successful "rod shot," or test-firing of some of the lasers.*

# 2001/2002 Accomplishments: NIF Line Replaceable Units

## *Line replaceable units installed for NIF Early Light*

*More than 120 LRUs of over a dozen types were fabricated, assembled, and installed to support the NEL activation schedule.*

A primary focus of the NIF project during the past two years has been producing, installing, and commissioning the laser hardware required to activate the facility's first four beamlines. This project-within-a-project, referred to as NIF Early Light or NEL, will provide early feedback on the producibility and performance of the NIF laser hardware prior to committing to contracts for full NIF quantities. While the laser beam enclosures in the first NIF laser bay are complete, the majority of the specialized laser hardware is installed into the beamline as Line Replaceable Units, or LRUs. These LRUs are precision optomechanical and electro-optic modules that contain the various optical components in the beamlines. The LRUs are being assembled and installed over a six-year period from 2002 through 2008.



More than 120 LRUs of over a dozen types were fabricated, assembled, and installed to support the NEL activation schedule. These precision assemblies are typically the size of a phone booth, and have kinematic mounts to position the optics in the beamline to within plus-or-minus 1 millimeter. Producing this large amount of hardware was accomplished through close partnerships with industry. Production engineering teams were assembled to determine the best contracting methods to procure each part and then to award and manage the many contracts with an eye toward the production quantities still to come. All of the LRUs required for NEL were delivered in time to meet the demanding schedule for NEL commissioning.

Contaminants on the NIF optics can result in damage when the high-energy laser pulse is applied. Therefore, the LRUs must be precision-cleaned to demanding requirements and assembled and installed in a manner that maintains their cleanliness. NIF's Optics Assembly Building (OAB) Class 100 clean room employs specialized robots and fixtures to minimize exposure of the optics to contamination. LRUs are transported and installed using specially designed hardware, including automatically guided vehicles called "transporters" and portable clean rooms equipped with precision installation mechanisms for inserting LRUs into NIF's beampath enclosures. Together, the OAB and transport and handling

teams installed all of the LRUs for NEL while maintaining stringent cleanliness and alignment requirements.

With the successful completion of LRU installation for NEL, laser commissioning activities have begun. These include aligning all of the laser beams, activating the amplifier power conditioning systems, and successfully firing the first integrated system shots on the laser.

***Left page:*** *Glass slab LRU being prepared for transport from the Optics Assembly Building (OAB) into Laser Bay 2.*

***Left page, inset:*** *The drawing shows a cutaway view of a NIF amplifier with glass slabs and flashlamps.*

***Right page:*** *Transport and handling systems install laser amplifier slab and flashlamp LRUs into the beampath enclosure.*

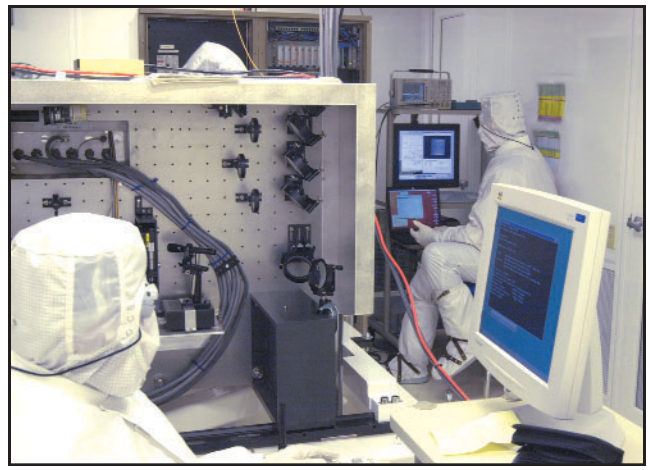
***Right page, inset:*** *Beam transport mirror LRUs undergo final assembly in the OAB.*

# 2001/2002 Accomplishments: NIF Computer Controls

## *Engineering rigor is key in the development of NIF's Integrated Computer Control System (ICCS)*

*Over the last two years, efforts by the development team have focused on the design, production, and installation of hardware and the development and testing of software.*

The National Ignition Facility (NIF), when completed, will employ 192 laser beamlines that will be focused on tiny, millimeter-size targets to study high-energy-density and fusion ignition physics. To function properly, control systems are required for precise automated alignment, beam diagnostics, power conditioning, and electro-optic subsystems. Additionally, NIF requires integration of approximately 60,000 control points, such as stepping motors, transient digitizers, and photodiodes, along with a variety of industrial controls. Five hundred sensor cameras will be employed to monitor the laser beams. Approximately 300 front-end processors will interface and control these various devices. The first four laser beams have been activated to prove the integrated laser and target area components before completing the rest of NIF.



Over the last two years, efforts by the development team have focused on the design, production, and installation of hardware and the development and testing of software. The highly-skilled team grew from about 60 to 110 people during this time, with nearly three-quarters involved in large-scale software engineering to produce the nearly 1 million source lines of code anticipated for the control system. To manage the large number of tasks required, ICCS and project leaders have followed the model employed by the aerospace industry to ensure rigorous hardware and software engineering practices were implemented. Configuration management systems and quality assurance processes were developed and put into place, and a testing group established formal quality controls.

Following this model, the ICCS team has been able to develop the hardware design and manufacturing of all needed customized equipment, including computer systems, interfaces, and controllers. All hardware for NIF's main control room and the first four beams in Laser Bay 2 is nearing completion and in commissioning; additional ICCS activities are currently in progress


(a)


(b)


(c)


(d)

for Switchyard 2 and the target area. Also completed is the Integrated Timing System, which generates and delivers hundreds of precisely-timed trigger pulses (with a precision of 20 picoseconds) to equipment throughout the laser and target areas.

The ICCS software environment incorporates Ada and Java object-oriented programming languages and uses CORBA distribution technology to enhance the openness of the architecture and portability of the software. During 2001 and 2002, incremental cycles of software construction and test have been carried out. Controls hardware and software were formally verified by offline tests in the ICCS Integration and Test Facility, followed by tests in integration laboratories using production laser equipment. After successful testing, the software is deployed to NIF and commissioned with the laser hardware. The team has met demanding production schedules and delivered nearly two-thirds of the software to the facility.

In October 2002, the first NIF “rod shot” was conducted on-schedule using the control system. Two months later in December, another milestone was reached as amplified test shots produced more than 43 kilojoules of infrared light in Laser Bay 2.

***Left page:*** *Dozens of control systems, such as this rack of motor controllers, have been installed in the NIF facility over the past two years.*

***Left page, inset:*** *Automatic alignment of the the preamplifier module and input sensor is tested in the lab.*

***Right page, inset (a):*** *Engineers and computer scientists at the ICCS Duty Engineer console prepare for laser shots.*

***Right page, inset (b):*** *Fast filter pinwheels under test in the ICCS Integration and Test Facility.*

***Right page, inset (c):*** *Power conditioning module under test in the Pulse Power Integration Lab.*

***Right page, inset (d):*** *Safety interlock PLC field I/O installed in the preamplifier maintenance area will assure personnel safety from laser and high-voltage hazards.*

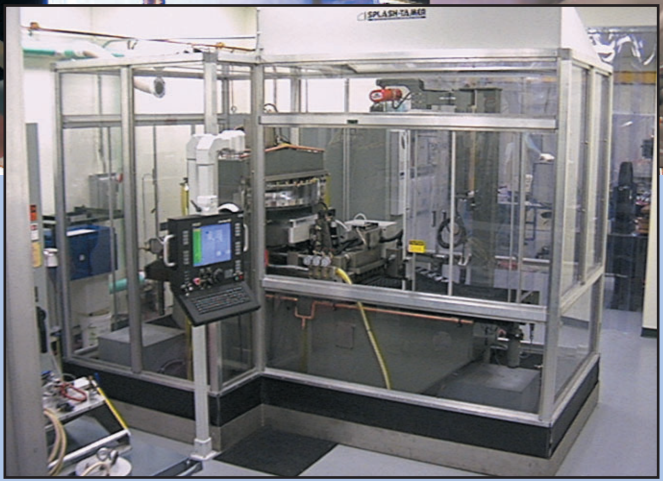

## *Advances in manufacturing technology yield KDP optics of unprecedented quality for NIF*

*The development of the technology to fabricate KDP optics to higher quality than ever before was a major undertaking over the last two years…*

The National Ignition Facility (NIF) is both the largest laser system and the largest optical instrument ever built, requiring 7500 large optics and more than 30,000 small optics to steer its laser beams through the approximately 1000-foot-long beampath onto millimeter- to centimeter-sized targets. One of the major technology developments for NIF is the production of very large, high-quality potassium dihydrogen phosphate (KDP) crystals. KDP crystals are important optical elements in NIF, serving two separate functions: first as part of an optical switch that uses polarization rotation to trap each laser beam in the main amplifier for multiple passes through the laser glass, and second as a frequency converter to change the laser light from infrared to ultraviolet. KDP is a very challenging material to fabricate and finish to NIF's required precision because it is brittle, thermally sensitive, and hygroscopic and so must be kept in a humidity-controlled environment at all times.

The development of the technology to fabricate KDP optics to higher quality than ever before was a major undertaking over the last two years, requiring advances in machining technologies applied to this special material. In order to meet NIF's exacting optics requirements, LLNL engineers, materials scientists, and laser technologists, in collaboration with our vendor, developed an elaborate fabrication process involving over 60 manufacturing operations to provide the greatest yield of precision KDP optics from each single large crystal. The diamond fly-cutting machines—designed and built by LLNL in partnership with industry and now installed at an industrial facility—employ a 100-kilogram aluminum fly-cutter spinning at 1000 rotations per minute on precision air bearings. Maximum error motion of the machines is less than 25 nanometers and asynchronous error motion is below 12 nanometers. The machine's speed can be controlled to better than 0.01 percent to maintain a crystal's flatness as it is being worked.

These achievements in machine design have made it possible to fabricate large-aperture (42 centimeters square) KDP optics that achieve the required surface

roughness over the full aperture, averaging less than 2 nanometers with no surface damage. Crystal alignment or phase match angle for frequency conversion can be held to be better than 10 microradians, including a transmitted wave-front gradient or nonlinear thickness variation that on average is better than 11 nanometers per centimeter.

In late 2002, KDP crystal manufacturing entered the pilot production phase and the NIF Project was on track to produce all the crystals needed for NIF Early Light (NEL) by the end of 2002.

***Left page:*** *A finished 42-centimeter-square optic undergoing precision cleaning.*

***Left page, inset:*** *This machine diamond fly-cuts the surface of the KDP crystal to the required phase-matching angle. Surfaces are machined relative to the crystal's axes so that phase matching is achieved at a specified tilt.*

***Right page:*** *A technician performs the initial cut of the KDP crystal, or boule, to form a rectangular slab oriented to the crystal phase axis.*

***Right page, inset:*** *One of the diamond fly-cutting machines designed and built by LLNL and now installed at our vendor's facility.*

# 2001/2002 Accomplishments: Biohazard Detection

## *BASIS deployment at the 2002 Winter Olympics helped assure public safety*

*LLNL engineers were responsible for developing the communications network to link together all the elements of BASIS.*

Even before the September 11, 2001 terrorist and subsequent anthrax attacks, engineers and scientists from Lawrence Livermore and Los Alamos national laboratories were developing the Biological Aerosol Sentry and Information System (BASIS) to rapidly detect, identify, and characterize the release of biological agents. BASIS was developed as a part of the overall security for the 2002 Winter Olympic Games in Salt Lake City. The system includes distributed sampling units, a relocatable field laboratory (RFL) for analyzing samples, and a command and control center. BASIS reduces the time for detecting a bioagent release from days or weeks to less than a day, allowing a rapid public health response. LLNL engineers were responsible for developing the communications network to link together all the elements of BASIS.

The BASIS communications engineering team developed a versatile system architecture using virtual private network (VPN) technology in such a way that a variety of dial-up, cellular, wireless, and wired Internet connections could be supported. The VPN uses encryption and tunneling protocols to protect the BASIS network from hackers on the public Internet. A private wireless network was also developed to bridge the gap to the nearest available Internet connection. Additionally, one of the team members created a software diagnostic to permit real-time monitoring of the BASIS network from anywhere on the VPN.

Because of increased security concerns after September 11, the BASIS program focused on early deployment and expanded coverage. The equipment suite was doubled so that half of it could be set up at the Olympics, while the other half was readied for transport and put on standby for deployment on 24-hour notice. As planned, BASIS was deployed at the 2002 Winter Olympic Games in support of federal, state, and local public health and law enforcement agencies. Sixteen distributed sampling units were located at sites in Salt Lake City and Park City where high concentrations of people were expected, while the RFL was set up at the Utah Department of Health. The system was operated successfully around the clock for over five weeks.

In the coming year, the BASIS communications team will focus on developing a new communications module that combines the functions of a VPN router, a next-generation cellular modem, and a wireless local



area network card into one small package. The team will also develop new VPN configurations that will greatly simplify future BASIS deployments.

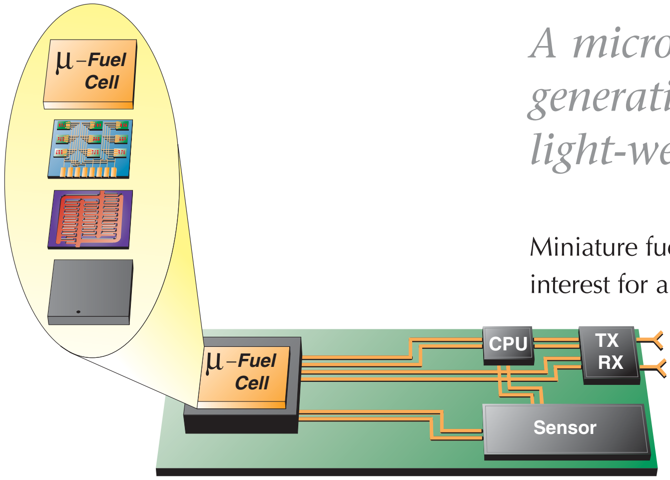
***Left page:*** *Sixteen BASIS sampling units like this one were installed in the Salt Lake City area.*

***Right page:*** *Overhead view of Olympic Square.*

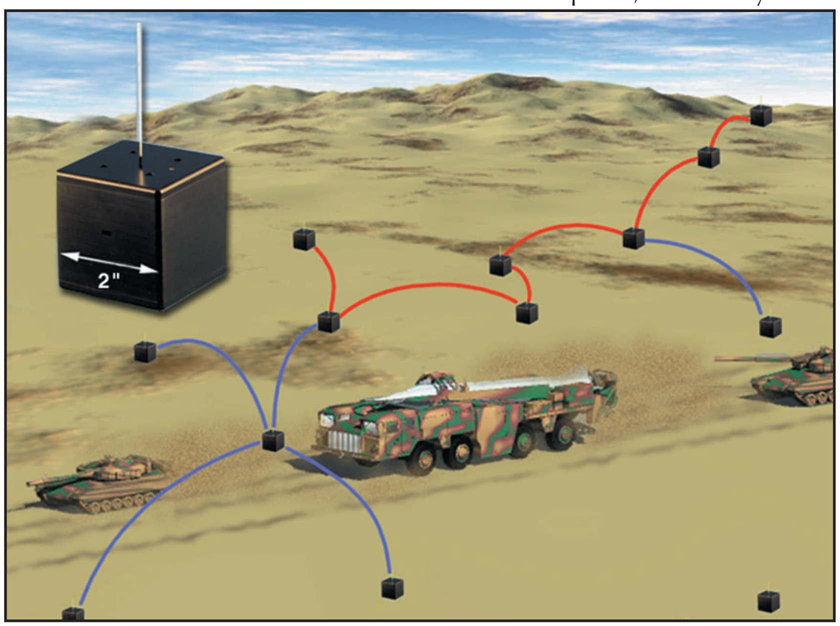
***Right page, inset:*** *Air samples undergo DNA analysis in the BASIS relocatable field laboratory.*

## *Microfluidic fuel processors promise miniature power sources*

*A microfluidic device technology enabling generic hydrogen generation...will lend itself to miniaturization for extremely compact, light-weight systems.*

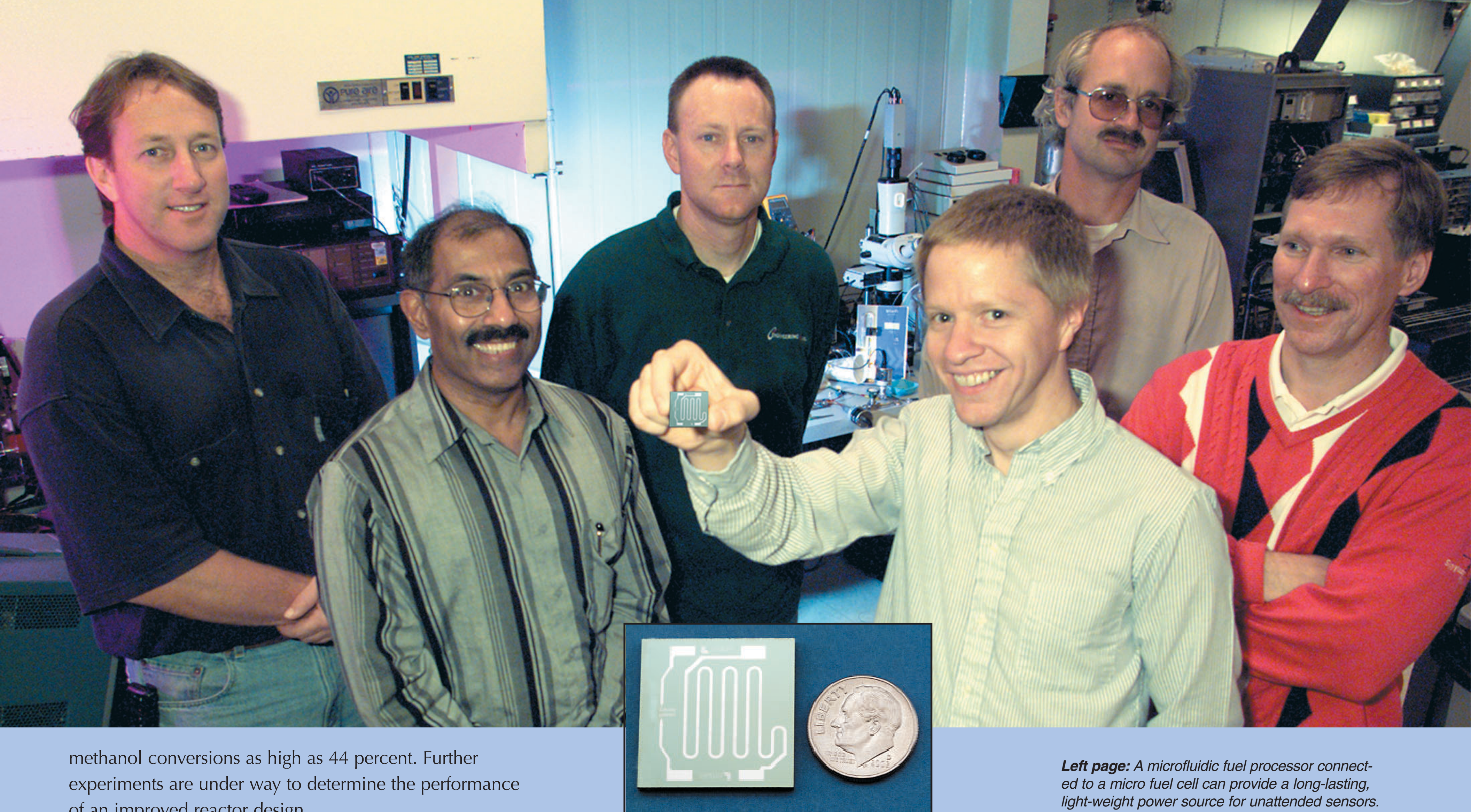



Miniature fuel cells have recently experienced renewed interest for applications in portable power generation. Portable power sources remain critical for all aspects of the military, weapons testing, and intelligence communities. While batteries have become a minor hindrance in the case of consumer portable electronics, they are simply not adequate for the advanced applications of remote reconnaissance, intelligence gathering, and telemetry. New power sources are required, with many of these having specific performance criteria for the direct application. A lighter-weight, longer-lasting power source provides new functionality to missions of all kinds, promising long-term cost benefits to all government agencies while enabling new levels of safety and security for personnel in the field.




Fuel cells store energy as fuel rather than as an integrated part of the structure of the device, as is the case with batteries. Current proton exchange membrane (PEM) fuel cells are limited to 3–15 percent methanol solution, thereby limiting their power and energy density. Our approach is to reform the methanol in a separate micro-reactor, convert it to hydrogen, and feed the hydrogen to the fuel cell. This approach allows us to exploit the very high energy densities of liquid fuels, using 50 percent methanol-water mixtures; higher concentrations may be possible by using novel water recovery designs. A microfluidic device technology enabling generic hydrogen generation will significantly extend the operating time of virtually any portable fuel cell power source, but most importantly, will lend itself to miniaturization for extremely compact, light-weight systems.

Our goal has been to design, fabricate, and test a microfluidic fuel processor for hydrogen generation for portable fuel cell power sources in order to reform hydrocarbon-based fuels having high specific energy content. With the hydrogen generation of the microfluidic fuel reformer, an integrated power solution targeting the 0.5–20-watt range may be realized. We have made significant advances by successfully depositing sputter-coated nickel and copper-oxide catalysts onto a reactor's microchannels and nanoporous membranes. Experiments performed using different flow patterns have yielded




methanol conversions as high as 44 percent. Further experiments are under way to determine the performance of an improved reactor design.

In the future, continuing efforts will result in a thermally integrated microdevice comprising a microreformer converting methanol to hydrogen, and a fuel cell delivering 500 milliwatts of power output.

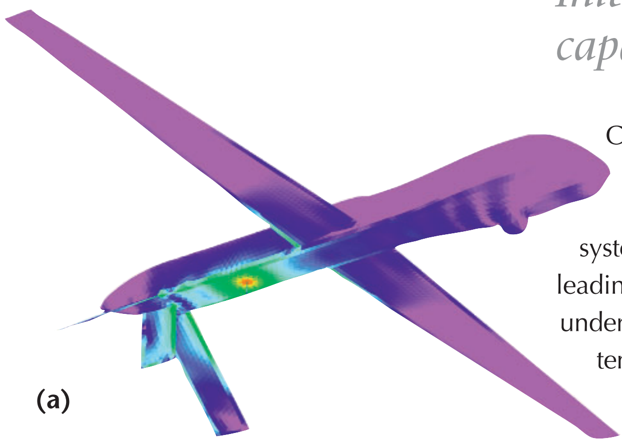
***Left page:*** *A microfluidic fuel processor connected to a micro fuel cell can provide a long-lasting, light-weight power source for unattended sensors.*

***Right page:*** *Fuel processor development team members (left to right): Jeff Morse, Ravi Upadhye, Tim Graff, Dave Sopclak, Mark Havstad, and Alan Jankowski.*

***Right page, inset:*** *A fuel cell microreactor is pictured next to a dime to show scale.*

## *Computer simulation capabilities have become crucial to national security and infrastructure research*

*Initially only an adjunct to physical tests, [computational engineering] capabilities are now central constituents of our work.*



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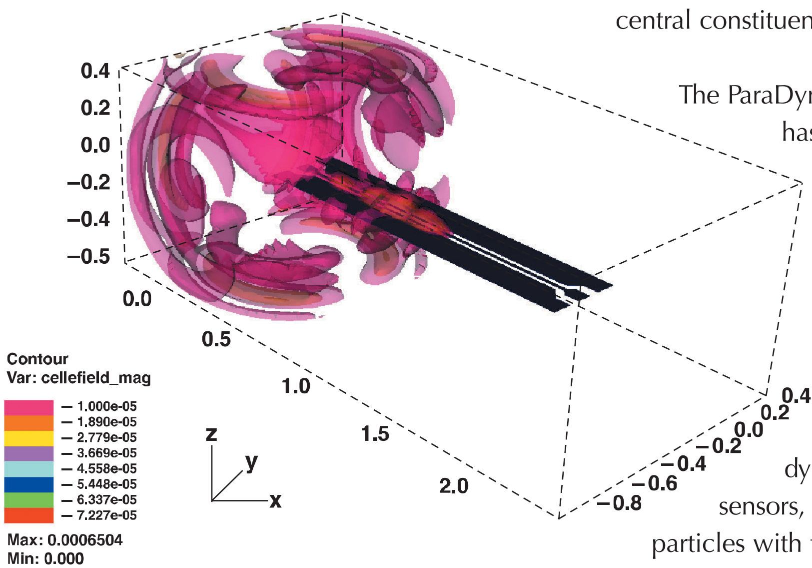
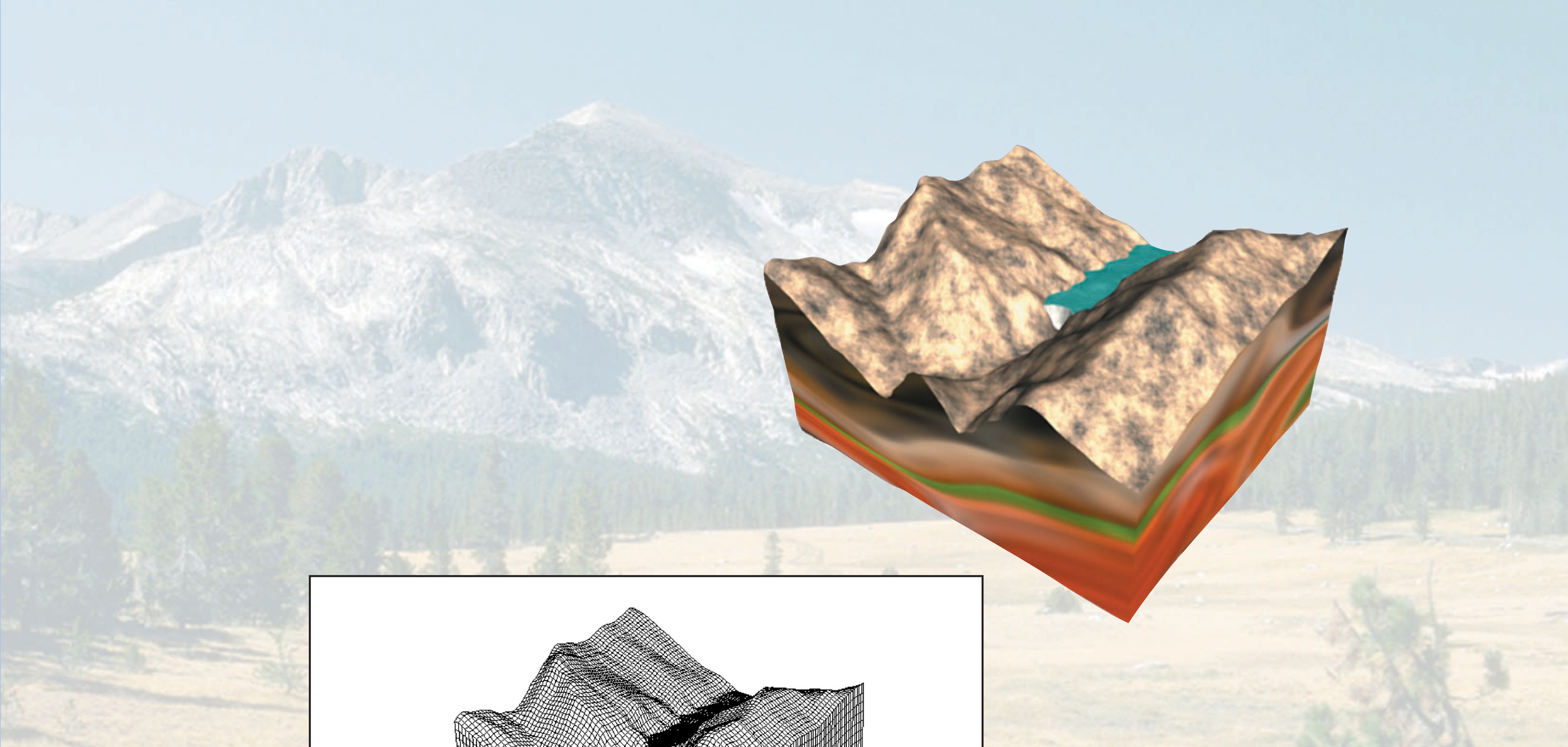



(b)

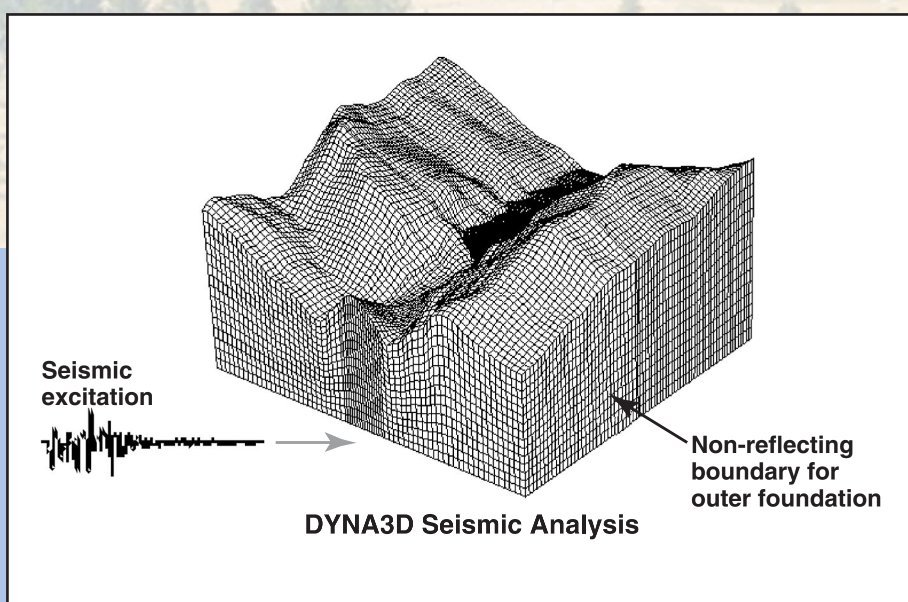
Computational engineering, which is the creation and use of numerical models to help understand and characterize the behavior of a component or system, is used extensively to both create futuristic leading-edge technology as well as develop greater understanding of existing engineered and natural systems. The national security mission of the Laboratory has motivated and supported much of Engineering's investment in simulation tools, and that trend has continued over the last two years. Initially only an adjunct to physical tests, these capabilities are now central constituents of our work.

The ParaDyn code for nonlinear structural dynamics has been widely used within ongoing nuclear weapon life extension projects both here and at Los Alamos National Laboratory. We have used and supported Defense and Nuclear Technologies' ALE3D hydrodynamics code for engineering studies such as interceptor impact lethality for the Missile Defense Agency. The flow dynamics within chemical and biological sensors, including the interactions of entrained particles with the channel walls and other features, are being modeled using an innovative lattice Boltzmann code to improve sensor sensitivity and efficiency. The communications links between Department of Defense (DOD) assets during critical operations are being addressed by an effort to predict the electronic battlefield environment. Also, the design of the next generation of Department of Defense mixed-signal systems (or systems-on-a-chip) is being addressed by applying an in-house developed code to high-frequency chip designs, thus integrating electromagnetic simulations with circuit models.

In addition to national security applications, we are also using state-of-the-art, sophisticated modeling capabilities to examine aspects of the nation's constructed infrastructure. We are currently simulating the Morrow Point Dam in Colorado in a study sponsored by the U.S. Bureau of Reclamation. To better characterize the seismic performance of this segmented concrete arch dam, not only are the dam and reservoir being modeled, but also the surrounding topography. The model is first gravity-loaded to establish the hydrostatic load response of the dam. Then the excitation of a representative seismic event is applied at the base of the model, and the resulting wave propagation and response of the dam and reservoir are computed. This model captures the effects of potential wave diffraction or focusing due to the topography. Also, the loading on the dam is more realistic as its periphery is not



uniformly excited. These efforts at increased fidelity have attracted the attention of academic researchers pursuing similar work.




***Left page, inset (a):*** *LLNL's EIGER code suite is used to predict the installed systems performance of key DOD assets. Here, the induced surface current on an unmanned air vehicle is shown. The radiation performance of this system can then be determined and optimized.*

***Left page, inset (b):*** *The EMSolve tools are being applied to the challenging problem of mixed-signal systems design. The field distribution around a high-frequency transmission line is shown in this figure. From this analysis, coupling to other components and circuits can be determined.*

***Right page:*** *An advanced finite element model of the Morrow Point Dam represents the dam, reservoir, and local topography in order to capture their interactions during an earthquake.*

# 2001/2002 Accomplishments: Facility Improvements

## *Consolidation of electronics and mechanical fabrication facilities reduces costs while increasing efficiencies*

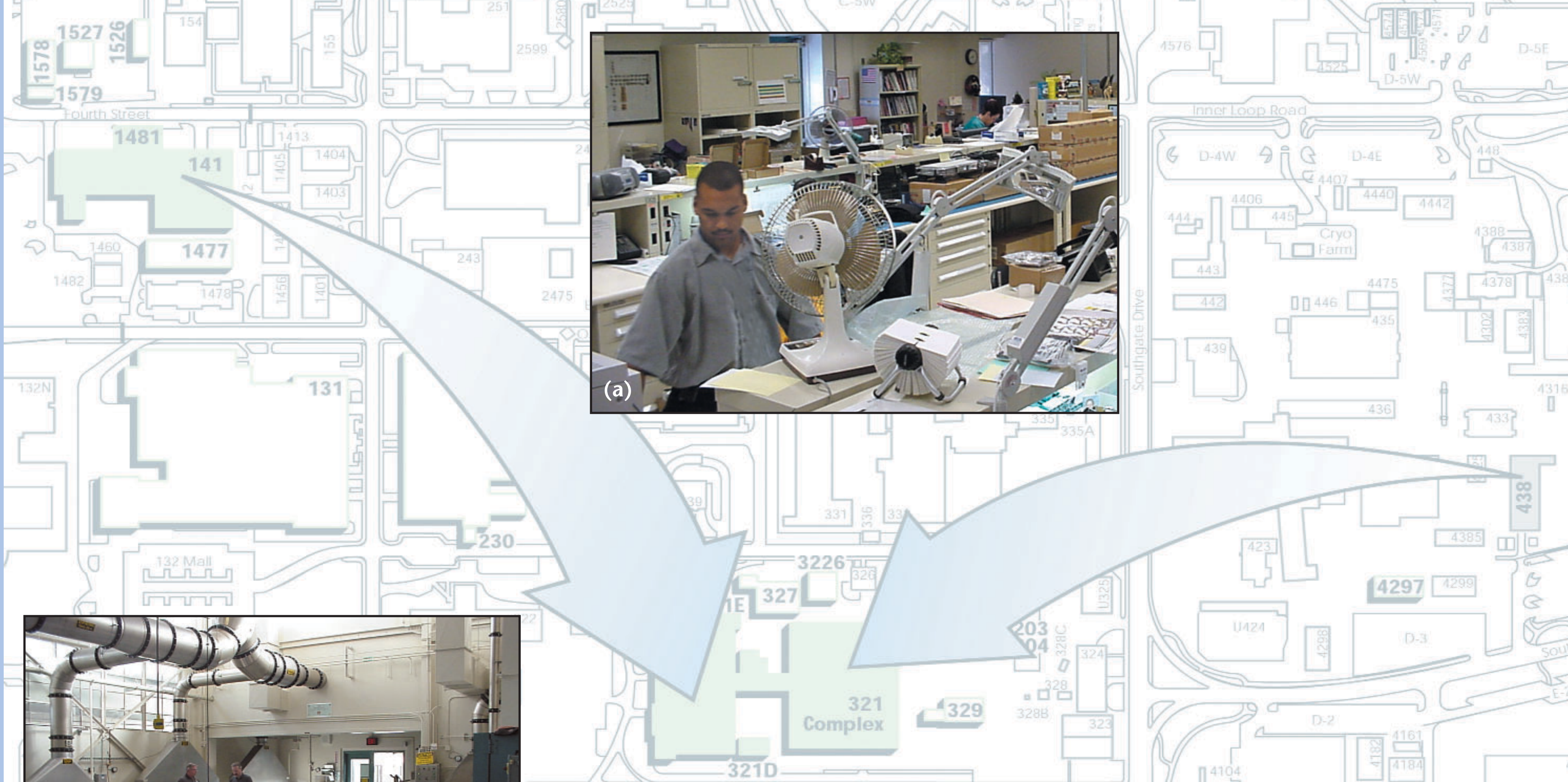
*Consolidation of Engineering fabrication into the Building 321 complex is eliminating redundancies and making Engineering more cost-effective.*

For the last several years, we have been working to consolidate several existing Electronics Engineering (EE) and Mechanical Engineering (ME) fabrication operations into the Building 321 area, turn over surplus space to the institution for reuse or demolition, and invest in the remaining facilities to improve the quality of space and reduce the maintenance costs. One of the main goals of this plan is to reduce the money Engineering spends each year to manage its facilities, which results in a corresponding reduction in the Organization Facility Charge (OFC).

The fabrication consolidation efforts have included moving EE fabrication from Building 141, Bay 1 to Building 321, moving the EE fabrication capabilities from Building 438 into Building 321, vacating Trailer 4326 (which was subsequently demolished), and moving the EE drafting group from Trailer 1481 to Building 321. This has allowed us to return Building 438 to the institution, while space in Building 141 and Trailer 1481 has been converted for other purposes. For example, a part of Building 141 that was formerly a high-bay area has been renovated with new modular offices, a conference room, and new bathrooms with showers. These improvements were targeted at creating high-quality space for Engineering personnel awaiting their security clearances.

In Building 321, improvements abound. Renovation efforts have provided an opportunity to install more environmentally friendly processes. By collocating EE and ME activities, duplicate plating equipment was eliminated. By upgrading equipment, the Building 321 welding shop was consolidated into approximately one-third of its original space, yet lost none of its capabilities. The precision machining group now enjoys a much larger area.

Additional benefits of the consolidation have been increased cooperation between previously separate EE and ME groups, a growing sense of Engineering team spirit, and improved morale amongst employees because of more efficient and capable work spaces. Now that they share facilities, the two fabrication groups are beginning to explore ways to share equipment and expertise—always with the goal of streamlining processes and increasing capabilities to support the Laboratory's programs.




With work approximately 95 percent complete, consolidation of Engineering fabrication into the Building 321 complex is eliminating redundancies and making Engineering more cost-effective, thus allowing us to continue to develop the unique world-class engineering resources that are the core of the Engineering Directorate's mission.

***Left page:*** *Upgrades to office and shop workspaces have improved efficiency and increased capabilities while also raising employees' morale.*

***Left page, inset:*** *The Surface Mount Technology and Through-Hole Technology work center in Building 321A offers state-of-the-art capabilities to satisfy programmatic needs.*

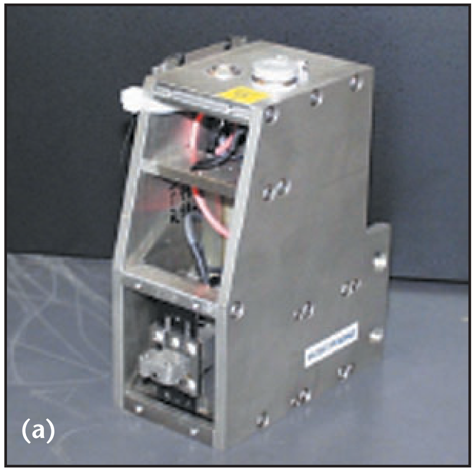
***Right page:*** *This map shows the locations of several Engineering-owned buildings. Many previously dispersed capabilities have been consolidated into the Building 321 complex.*

***Right page, inset (a):*** *The new Electronics Engineering Fabrication and Assembly work center in Building 321.*

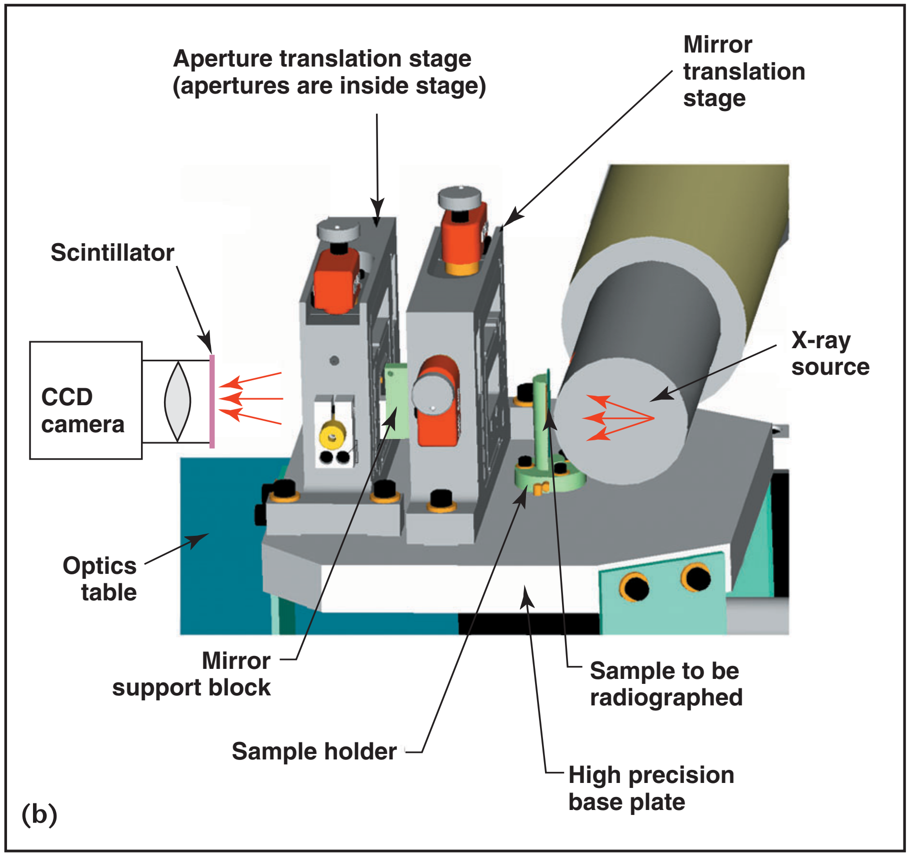
***Right page, inset (b):*** *The Special Processing work center performs chemical machining and milling of specialized parts in a variety of configurations and materials. The new location allows for expanded capabilities if needed.*

# New Venture: Mesoscale Initiative

The Engineering Directorate has begun a major effort to prepare for the future fabrication, assembly, and characterization of targets to be fielded on high-power laser systems such as the National Ignition Facility. Called the Mesoscale Initiative, it has as its goal the development of capabilities needed to fabricate target assemblies for the Defense and Nuclear Technologies High-Energy-Density Experimental Science (HEDES) Program. A number of these targets will require surface finishes in the 50–100 nanometer range, and surface features approaching one micrometer. Targets could have planar, cylindrical, or spherical geometries in materials that vary from very low-density foams such as aerogels, to high-density, high-Z shells serving as high-pressure fuel capsules. The targets could have 1-, 2-, or 3-D features on their surfaces, with feature size in the micrometer to tens-of-micrometers regime. The HEDES share of the NIF laser test shot schedule amounts to 200 to 300 shots a year; of that number, we estimate that 80 to 90 percent of the targets on those shots can most likely be produced with extensions to existing capabilities. The Mesoscale Initiative is focused on the more difficult targets remaining. Therefore,

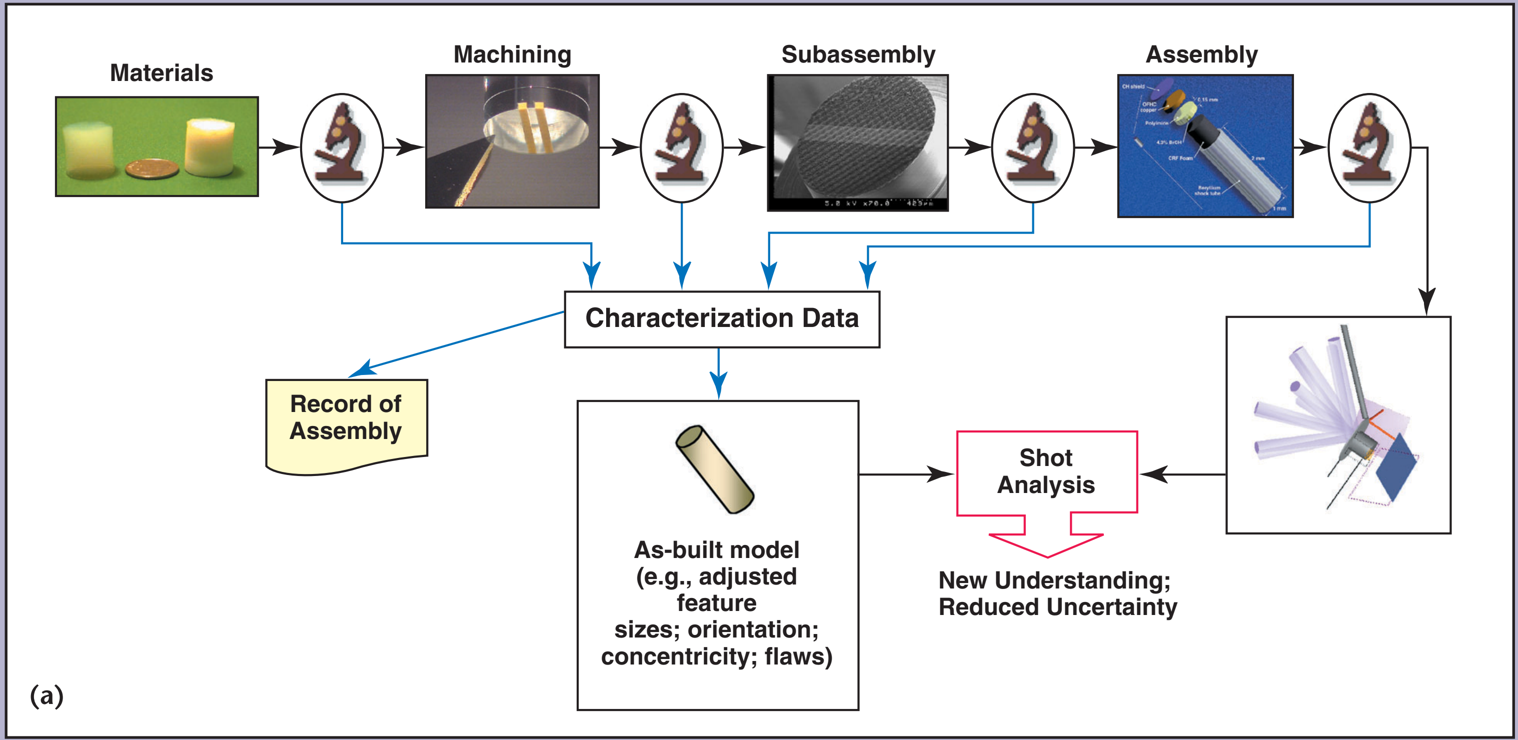



a successful Mesoscale Initiative will result in a capability that can produce this wide range of targets in sufficient numbers for the HEDES program, as well as provide capabilities to the inertial confinement fusion (ICF) and outside user community for their target needs. To reach that end, we are coordinating various research and technology efforts to ensure the proper capabilities are being developed and to do feasibility studies of new approaches to yield these capabilities.

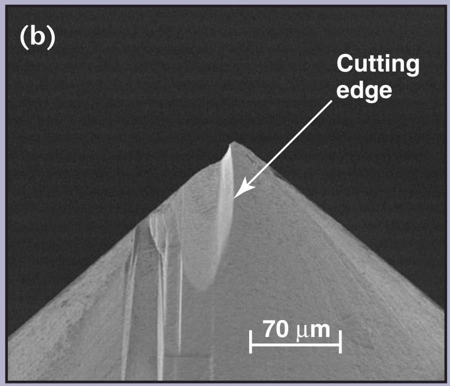



Fabricating targets is just part of the process. Once fabricated, the targets (which are usually made up of several components) must be assembled and characterized. Thus, the Initiative has six elements: material synthesis, material removal, material deposition, metrology of components, assembly, and characterization of the assembly.

In FY01–02, Engineering successfully proposed three Laboratory Directed Research and Development (LDRD) Exploratory Research (ER) projects that are critical to the Mesoscale Initiative. The first LDRD project is a continuation of a mid-year proposal, proposed to design and build an x-ray microscope capable of characterizing small (approximately 1 centimeter) targets to submicrometer resolution. A second LDRD is studying the enhancement of a fast servo tool to be added to the z-axis of a diamond turning machine. By increasing the speed this tool can move in and out, we can greatly enhance the material removal on complex, 3-D features. The third LDRD is studying the material removal characteristics of an ultra-short pulse laser. Here, experiments are coupled to modeling efforts to see if a deterministic behavior can be identified and if these lasers are capable of delivering the surface finishes required.




In addition to the ER projects, Engineering and the Chemistry & Materials Science Directorate also proposed a Strategic Initiative on the characterization of future target assemblies. As critical as developing fabrication and assembly techniques, the characterization is essential in providing the target designer with "as-built" measurements of component placement, gaps, concentricity, deformations, and so forth that are critical to performing an accurate target simulation on a computer. Four techniques were included in the proposal: an x-ray microscope, proton radiography, nuclear magnetic resonance (NMR) on foams, and high-frequency acoustics. Each of these techniques would yield a specific piece of information on the target assembly.




***Left page, inset (a):*** *100-Hz commercial fast tool servo owned by LLNL.*

***Left page, inset (b):*** *A geometric model of the base of an x-ray microscope that will be used for characterizing target assemblies. The instrument should provide submicrometer resolution of an object over a quarter-millimeter field of view.*

***Right page, inset (a):*** *Characterization must be an integral part of target fabrication. The non-destructive methods proposed in our Strategic Initiative will provide data to improve simulations using as-built target models. They will also provide a better understanding of the experimental results. Both will contribute to a new understanding of high-energy-density physics and reduce uncertainties.*

***Right page, inset (b):*** *We are investigating the use of ultra-short pulse lasers to produce extremely precise tools that will in turn be used in producing submicrometer features on laser targets. Early attempts yielded this cutting edge in a diamond tip.*

# Future Priorities


(a)

Engineering is highly regarded as the backbone of the Laboratory, the organization that provides expertise when programs require it, reassigns Engineering personnel when programs are completed, and develops critical skills to meet future priorities. After a decrease in Engineering's workforce from 3000 to 2000 employees over 12 years, the last few years have seen a significant increase in hiring: almost 290 employees hired in FY02, with 40 percent new graduates.

As the Laboratory's national security mission evolves to respond to new national priorities such as counter-terrorism, Engineering's priorities must keep pace. It is vital to maintain a robust workforce that can meet the demanding timeline of the National Ignition Facility commissioning and operation, fulfill the engineering requirements of defense and national security programs, and propel the frontiers of new engineering science and technologies. Therefore, our top priorities for 2003 are:


(b)

- Achieve engineering milestones for NIF Early Light (NEL) and subsequent commissioning and experimental activities.
- Fulfill commitments to the W80 program and lead in Engineering-based stockpile stewardship.
- Organize to support the new federal Department of Homeland Security.
- Continue to set the Laboratory standard for people management in such areas as performance management and leadership development.
- Invest in people, with emphasis on recent hires and the Engineering work environment.
- Provide opportunities for career growth of Engineering personnel so that they are prepared to take on a variety of programmatic and institutional leadership roles.
- Implement additional Survey Action Team (SAT) recommendations from the employee survey and serve as the pilot organization where appropriate. Continue the restarted machinist apprenticeship program.
- Continue Engineering facility and infrastructure revitalization, and develop a longer-term facilities and equipment strategic plan.

- Develop a science and technology investment strategy that aligns with the overall Laboratory plan.

- Maintain initiatives related to safety and security. Ensure proper focus and attention on all matters pertaining to environment, safety, and health and the new Integrated Safeguards and Security Management program.

***Left page, inset (a):*** *In the wake of the September 11, 2001 tragedy, President Bush and Congress acted to create the Department of Homeland Security. Engineering and the rest of the Laboratory will be at the forefront, supporting the new department with science and technology to help keep our nation secure.*

***Left page, inset (b):*** *A series of highly successful NIF test shots at the end of 2002 has paved the way for NIF Early Light, or NEL, in spring 2003: the transport of four ultraviolet beams of laser light into the target chamber.*

***Right page, insets (a) and (b):*** *Engineering's Leadership Development Program is designed to build a pool of trained younger employees ready to take on leadership tasks, and also provides advanced training for current leaders within Engineering. The Technical Administrative Leadership Program provides similar training opportunities for Engineering employees in technical and administrative career paths. Recent participants in both programs are shown.*

***Right page, inset (c):*** *Jason Carroll (left) and Paul Alexander (center) are the first two machinist apprentices hired under Engineering's revived apprentice program; on the right is program coordinator John Fry. Reinstituted in response to feedback received from the all-employee survey conducted in 2001, Engineering's apprentice program provides a hands-on way of transferring skills, knowledge, and ability to new people.*

## R&D 100 Awards

**Silicon Monolithic Microchannel (SiMM) Laser Diode Array**
Joseph J. Satariano, Jacqueline J. Crawford, Barry L. Freitas, Gary E. Loomis, Terri L. Delima-Hergert, Dave A. Van Lue, Kurt P. Cutter, Everett J. Utterback, Catherine E. Reinhardt

**Solid-State Heat-Capacity Laser (SSHCL)**
Balbir S. Bhachu, William J. Manning, Scott N. Fochs, James D. Wintemute, Steven B. Sutton, Georg F. Albrecht, Mark D. Rotter

**Production-Scale Thin-Film Coating Tool**
James A. Folta, Mark A. Schmidt, R. Frederick Grabner

**STIM-2002 TENS Pain Management Device**
Theodore T. Saito

## Professional Honors and Offices

**American Glovebox Society**
Board of Directors: Larry J. Walkley

**American Nuclear Society**
Chairman, Northern California Section: Mark A. Mitchell

**American Society of Mechanical Engineers**
Principal Editor, Transportation, Disposal, and Storage of Radioactive Materials and Technical Sessions Developer (ASME Pressure Vessels and Piping Conference, Atlanta, GA): Ronald S. Hafner; Contributing Editor, Seismic Engineering and Technical Sessions Chairman (ASME Pressure Vessels and Piping Conference, Atlanta, GA): Stephen C. Lu

**California Governor's Task Force for the Safe Delivery of Fuels**
Chairman, Subcommittee for Field Testing: David B. McCallen

**The Institute of Electrical and Electronics Engineers**
Treasurer, 2004 Nuclear Science Symposium and Medical Imaging Conference: Anthony D. Lavietes; Assistant Editor, IEEE Nuclear Science Symposium: Brad W. Sleaford; Chairman, Laser Pulsed Power Session of Pulsed Power Plasma Science Conference: Douglas W. Larson; Co-Chairman, Technical Program, Pulsed Power Plasma Science Conference: Mark A. Newton

**Memorial Institute for the Prevention of Terrorism**
Panel Member, Panel to Review Overall Research Program: Raymond P. Mariella, Jr.

**National Academies/National Research Council**
Panel Member, Panel on Materials and Manufacturing Processes for Advanced Sensors: Raymond P. Mariella, Jr.

**Project Management Institute**
Certified Project Management Professional: Karl H. Krause

**SPIE–The International Society for Optical Engineering**
Member, Editorial Board and Program Committee, Subsurface Sensing Technologies and Applications Section: Rexford M. Morey; Photonics West Special Session on LLNL: Steven W. Bond

**University of the Pacific, Stockton**
Steering Committee for Biomedical Engineering: Kevin C. O'Brien


## Selected Awards and Honors

### *2001*

**California Polytechnic University, San Luis Obispo**
Exceptional Leadership Award: Robert B. Addis

**Department of Energy**
1998 Defense Programs Award of Excellence: Daniel C. Badders, Jeffrey N. Hockman
Federal Laboratory Consortium Award for Excellence in Technology Transfer: Kevin C. O'Brien

**International SEMATECH**
Corporate Excellence Award: Abbie L. Warrick

### *2002*

**The Institute of Electrical and Electronics Engineers**
Distinguished Technical Achievement Award: Jim Candy

**Department of Energy**
Technical Excellence in Weapons Design and Engineering: Anthony H. DePiero, Mary F. Foltz, Peter J. Raboin, Gordon P. Spellman, P. Derek Wapman, Thomas M. Anklam, Steven E. Benson, Kenneth W. Dolan, David S. Hiromoto, Thomas C. Meier, Shawn C. Peterson, William J. Poulos, James M. Sevier, Jr.
Technical Excellence in ASCI Computing: Joseph A. Slavec

***Left page:*** *Karl Krause, Chief Engineer and leader of Engineering's Project Management and Systems Engineering initiatives, was certified as a Project Management Professional by the Project Management Institute.*

***Right page:*** *Mark Schmidt, a process engineer, places an optical substrate into the Mag-4 multilayer deposition system. Mark was part of the team awarded an R&D 100 Award in 2002 for the Production-Scale Thin-Film Coating Tool.*

## Patents

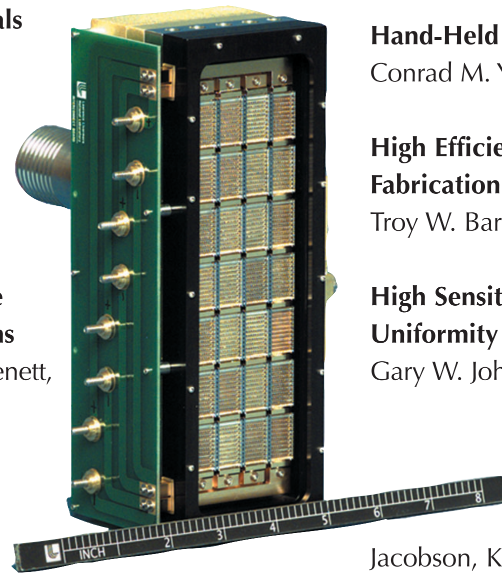
### *2001*

**Adhesion Layer for Etching of Tracks in Nuclear Trackable Materials**
Jeffrey D. Morse, Robert J. Contolini

**Amorphous-Diamond Electron Emitter**
Steven Falabella

**Apparatus for Loading Shape Memory Gripper Mechanisms**
Abraham P. Lee, William J. Benett, Daniel L. Schumann, Peter A. Krulevitch, Joseph P. Fitch

**Bi-Stable Optical Element Actuator Device**
Fred R. Holdener




**Enhanced Modified Faraday Cup for Determination of Power Density Distribution of Electron Beams**
John W. Elmer, Alan T. Teruya

**Fabrication of Precision High-Quality Facets on Molecular Beam Epitaxy Material**
Holly E. Petersen, William D. Goward, Sol P. Dijaili

**Generation of Low Work Function, Stable Compound Thin Films by Laser Ablation**
Long N. Dinh, William McLean II, Mehdi Balooch, Edward J. Fehring, Jr., Marcus A. Schildbach

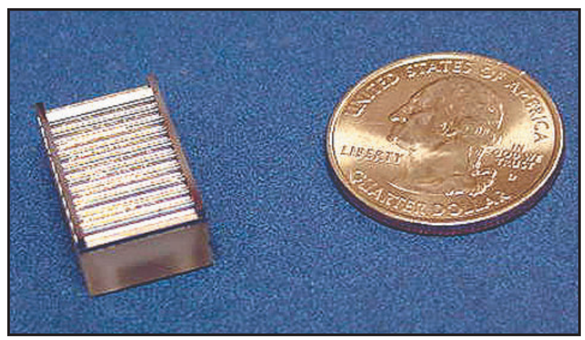
**Hand-Held Multiple System Gas Chromatograph**
Conrad M. Yu

**High Efficiency Replicated X-Ray Optics and Fabrication Method**
Troy W. Barbee, Jr., Stephen M. Lane, Donald E. Hoffman

**High Sensitivity Charge Amplifier for Ion Beam Uniformity Monitor**
Gary W. Johnson

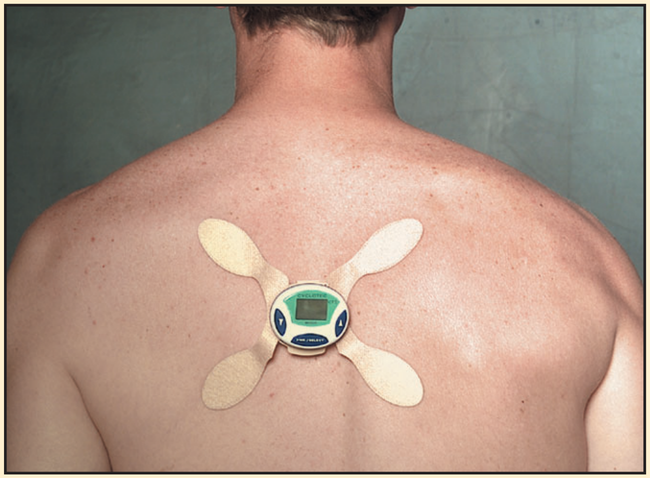
**High Voltage Photovoltaic Power Converter**
Ronald E. Haigh, Steve Wojtczuk, Gerard F. Jacobson, Karla G. Hagans

**Highly Damped Kinematic Coupling for Precision Instruments**
Layton C. Hale, Steven A. Jensen



**Method for Vacuum Fusion Bonding**
Harold D. Ackler, Stefan P. Swierkowski, Lisa A. Tarte, Randall K. Hicks

**Microfabricated Instrument for Tissue Biopsy and Analysis**
Peter A. Krulevitch, Abraham P. Lee, M. Allen Northrup, William J. Benett



**Microfluidic Interconnects**
William J. Benett, Peter A. Krulevitch

**Micromachined Low Frequency Rocking Accelerometer with Capacitive Pickoff**
Abraham P. Lee, Jonathan N. Simon, Charles F. McConaghy

**Modified Electrokinetic Sample Injection Method in Chromatography and Electrophoresis Analysis**
J. Courtney Davidson, Joseph W. Balch

**Monolithic Laser Diode Array with One Metallized Sidewall**
Barry L. Freitas, Jay A. Skidmore, John P. Wooldridge, Mark A. Emanuel, Stephen A. Payne

**NOx Reduction System Utilizing Pulsed Hydrocarbon Injection**
Raymond M. Brusasco, Bernardino M. Penetrante, George E. Vogtlin, Bernard T. Merritt

**Paper Area Density Measurement from Forward Transmitted Scattered Light**
Jackson C. Koo

**Pedestal Substrate for Coated Optics**
Layton C. Hale, Terry N. Malsbury, Steven R. Patterson

**Process for Fabricating Composite Material Having High Thermal Conductivity**
Nicholas J. Colella, Howard L. Davidson, John A. Kerns, Daniel M. Makowiecki

**Process for Manufacturing Hollow Fused-Silica Insulator Cylinder**
Stephen E. Sampayan, Derek E. Decker, David M. Sanders

**System and Method for Chromatography and Electrophoresis Using Circular Optical Scanning**
Joseph W. Balch, Laurence R. Brewer, James C. Davidson, Joseph R. Kimbrough

**System and Method for Optically Locating Microchannel Positions**
Laurence R. Brewer, Joseph Kimbrough, Joseph Balch, J. Courtney Davidson

**Two Position Optical Element Actuator Device**
Fred R. Holdener

**Use of a Hard Mask for Formation of Gate and Dielectric Via Nanofilament Field-Emission Devices**
Jeffrey D. Morse, Robert J. Contolini

**Vacuum Fusion Bonded Glass Plates Having Microstructures Thereon**
Stephan P. Swierkowski, James C. Davidson, Joseph W. Balch

**Vacuum-Surface Flashover Switch with Cantilever Conductors**
Stephen E. Sampayan, Hugh C. Kirbie

***Left page:*** *Dave McCallen was named Chairman of the Subcommittee for Field Testing, California Governor's Task Force for the Safe Delivery of Fuels.*

***Left page, insets:*** *Engineering personnel shared in an R&D 100 Award for the Silicon Monolithic Microchannel (SiMM) Laser Diode Array. A 41-kilowatt laser diode array constructed from 28 individual packages of SiMMs is shown. Below that, a single SiMM package is pictured next to a quarter for scale.*

***Right page:*** *Participation in the development of the STIM-2002 TENS pain management device earned Engineering recognition in another R&D 100 Award-winning effort.*

# Honors, Awards, and Patents

## *2002*

**Alternating-Polarity Operation for Complete Regeneration of Electrochemical Deionization System**
Tri D. Tran, David J. Lenz

**Apparatus and Method for Collection and Concentration of Respirable Particles into a Small Fluid Volume**
Jonathan N. Simon, Steve B. Brown

**Apparatus for Improving Performance of Electrical Insulating Structures**
Michael J. Wilson, David A. Goerz

**Charge Amplifier with Bias Compensation**
Gary W. Johnson

**Coatings on Reflective Mask Substrates**
William Man-Wai Tong, John S. Taylor, Scott D. Hector, Pawitter J. S. Mangat, Alan R. Stivers, Patrick G. Kofron, Matthew A. Thompson

**Compact Multiwavelength Transmitter Module for Multimode Fiber Optic Ribbon Cable**
Robert J. Deri, Michael D. Pocha, Michael C. Larson, Henry E. Garrett

**High Average Power Scaleable Thin-Disk Laser**
Raymond J. Beach, Eric C. Honea, Camille Bibeau, Stephen A. Payne, Howard Powell, William F. Krupke, Steven B. Sutton

**High-Speed Pulse-Shape Generator, Pulse Multiplexer**
Scott C. Burkhart

**Low Cost Impulse Compatible Wideband Antenna**
Erwin T. Rosenbury, Gerald K. Burke, Scott D. Nelson, Robert D. Stever, George K. Governo, Donald J. Mullenhoff

**Metals Removal from Spent Salts**
Peter C. Hsu, Erica H. von Holtz, David L. Hipple, Leslie J. Summers, William A. Brummond, Martyn G. Adamson

**Method for Improving Performance of Highly Stressed Electrical Insulating Structure**
Michael J. Wilson, David A. Goerz

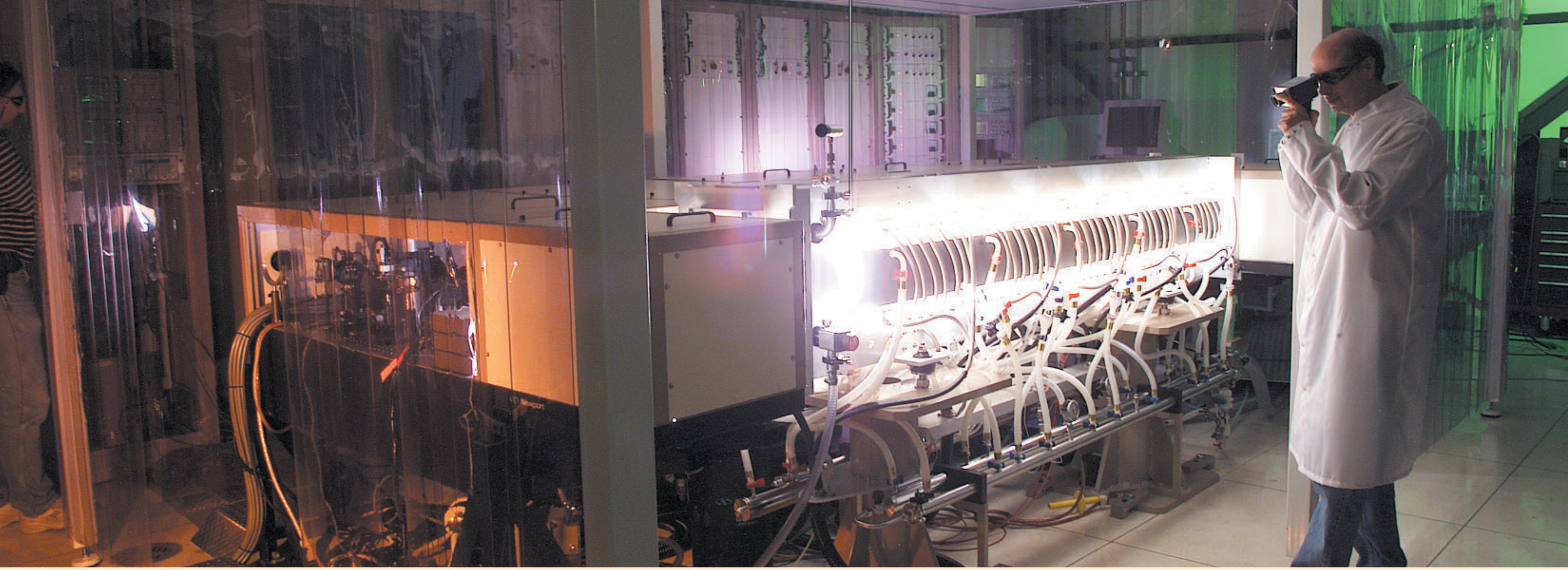
**Microfluidic DNA Sample Preparation Method and Device**
Peter A. Krulevitch, Robin R. Miles, Xiao-Bo Wang, Raymond P. Mariella, Jr., Peter R. C. Gascoyne, Joseph W. Balch

**Miniature X-Ray Source**
James E. Trebes, Gary F. Stone, Perry M. Bell, Ronald B. Robinson, Victor I. Chornenky

**Optical Coherence Tomography Guided Dental Drill**
Luiz B. Da Silva, Bill W. Colston, Jr., Dale L. James

**Opto-Acoustic Recanilization Delivery System**
Steven R. Visuri, Luiz B. Da Silva, Peter M. Celliers, Richard A. London, William Benett, Kathryn Broughton, Victor Esch

**Plasma-Assisted Catalytic Storage Reduction System**
Bernardino M. Penetrante, George E. Vogtlin, Bernard T. Merritt, Raymond M. Brusasco



**Portable Gas Chromatograph Mass Spectrometer for On-Site Chemical Analyses**
Jeffrey S. Haas, John F. Bushman, Douglas E. Howard, James L. Wong, Joel D. Eckels

**Printed Circuit Board for a CCD Camera Head**
Alan D. Conder

**Rotational Rate Sensor**
Steven L. Hunter

**Self Adjusting Inclinometer**
Steven L. Hunter

**Solar Cell Module Lamination Process**
Paul G. Carey, Jesse B. Thompson, Randy C. Aceves

**Sputtering Process and Apparatus for Coating Powders**
Daniel M. Makowiecki, John A. Kerns, Craig S. Alford, Mark A. McKernan

**System and Method for 100% Moisture and Basis Weight Measurement of Moving Paper**
Jose E. Hernandez, Jackson C. Koo

**System and Method for Characterizing Voiced Excitations of Speech and Acoustic Signals, Removing Acoustic Noise from Speech, and Synthesizing Speech**
Greg C. Burnett, John F. Holzrichter, Lawrence C. Ng

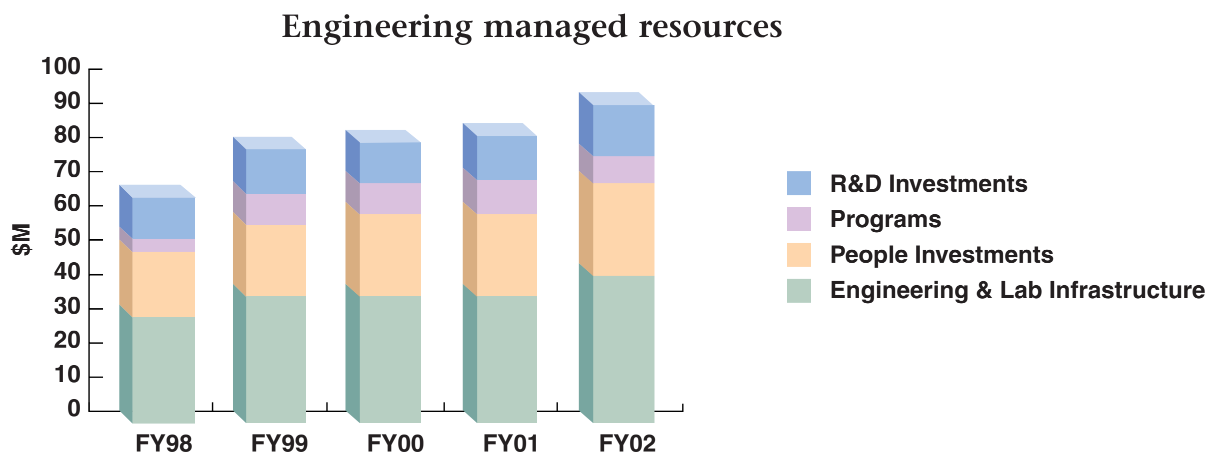
**Thermally Robust Semiconductor Optical Amplifiers and Laser Diodes**
Sol P. Dijaili, Frank G. Patterson, Jeffrey D. Walker, Robert J. Deri, Holly Petersen, William Goward

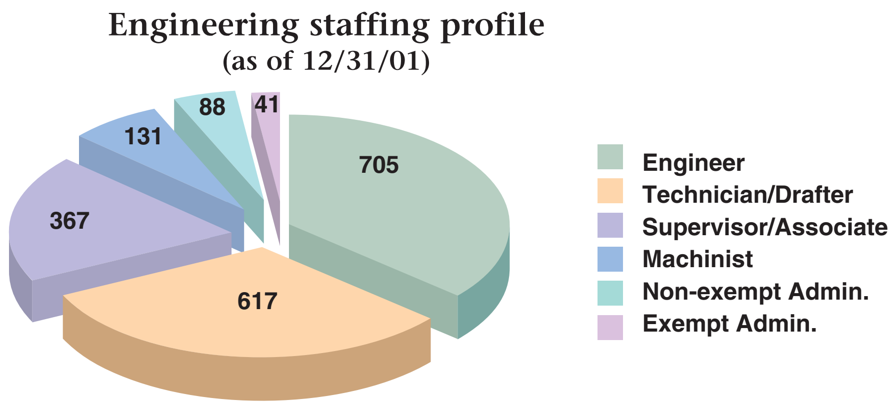
**Tiltmeter Leveling Mechanism**
Steven L. Hunter, Carl O. Boro, Alvis Farris

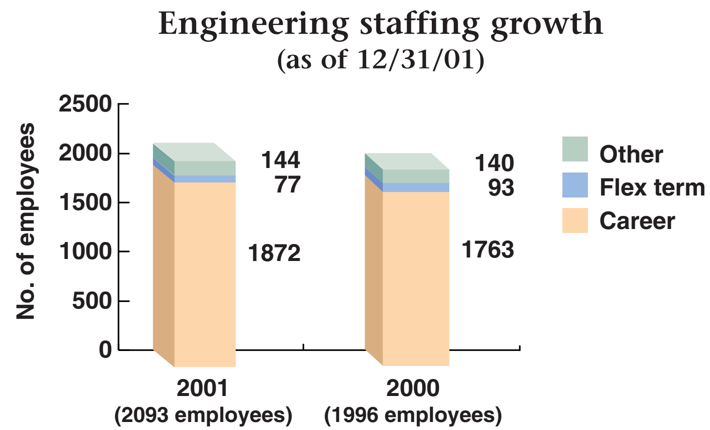
***Left page:*** *Engineer Abbie Warrick was honored in 2001 with International SEMATECH's Corporate Excellence Award for her part in the development and fabrication of programmed defect reference wafers for the Intentional Defect Arrays project.*

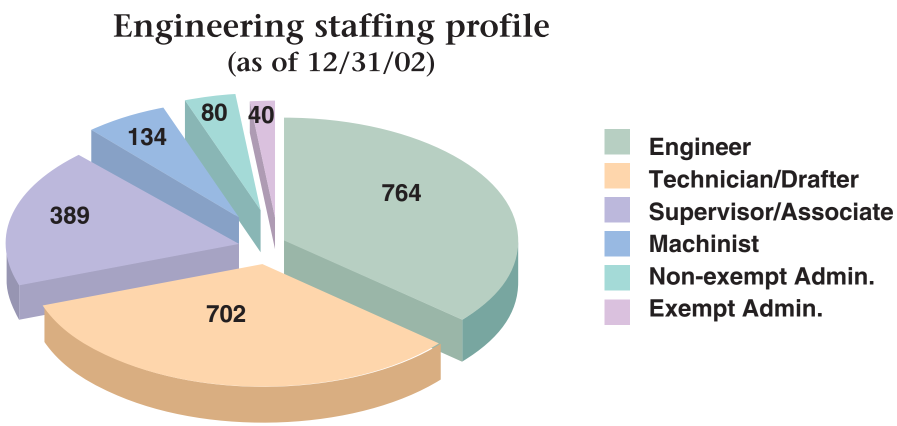
***Right page:*** *Balbir Bhachu, a laser technician, monitors the performance of the solid-state heat-capacity laser (SSHCL). Engineers were part of the team that developed the SSHCL, which garnered yet another R&D 100 Award in 2002.*

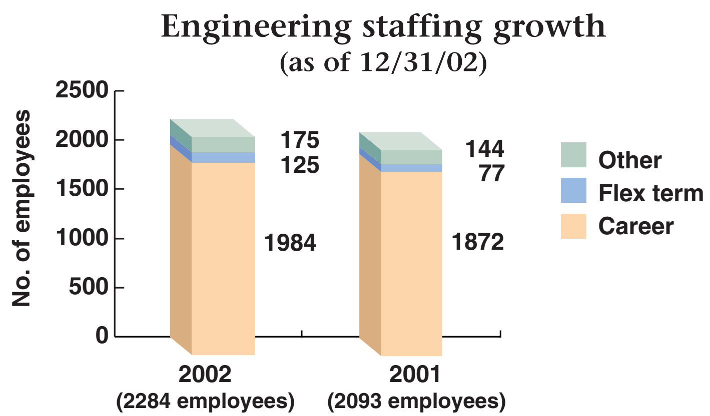
# Engineering Statistics



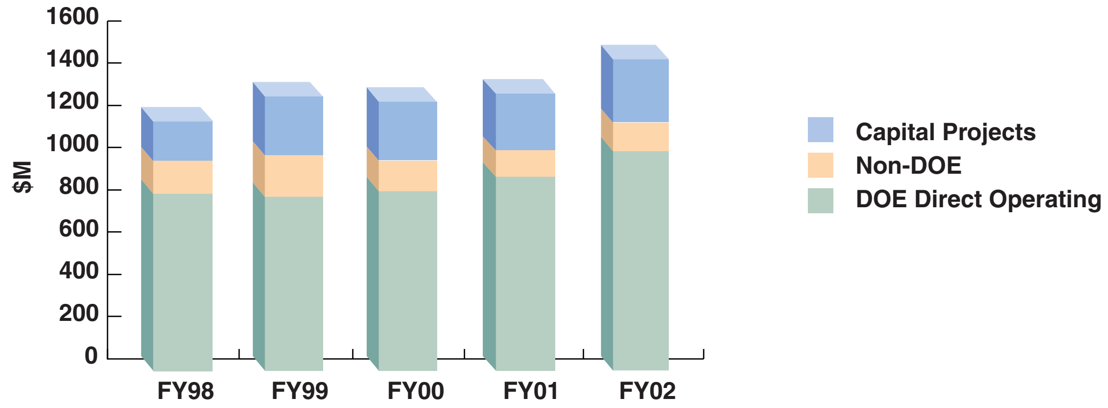



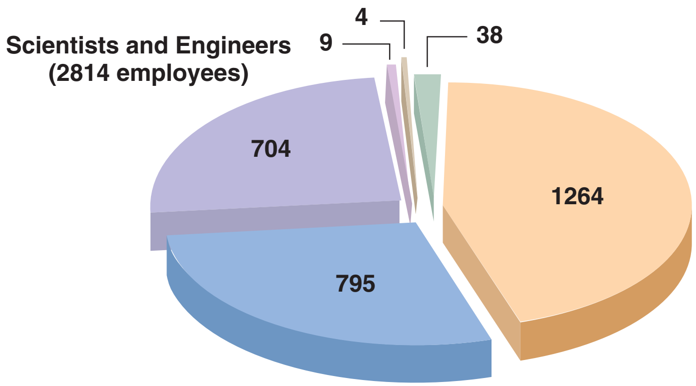



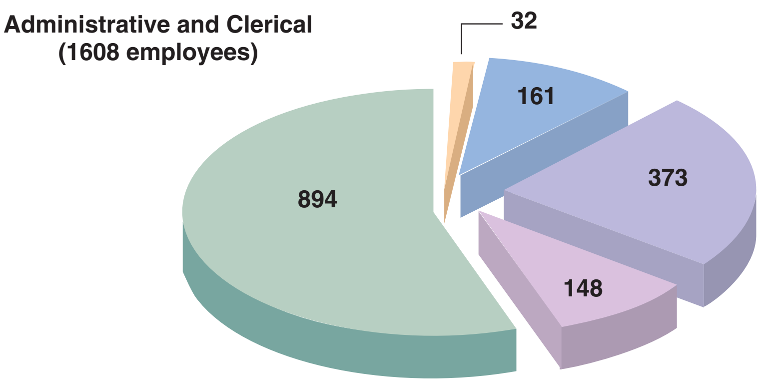
# Laboratory Statistics

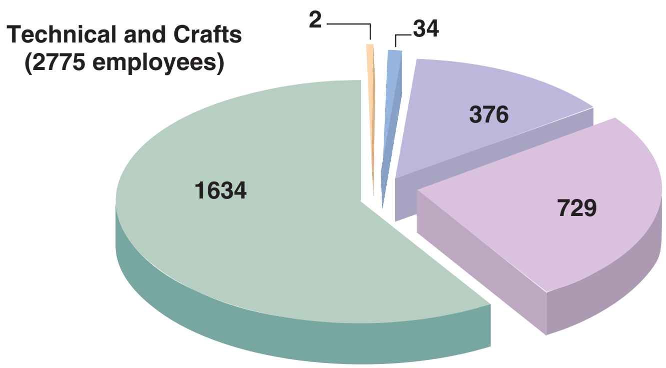
## Laboratory five-year revenue profile

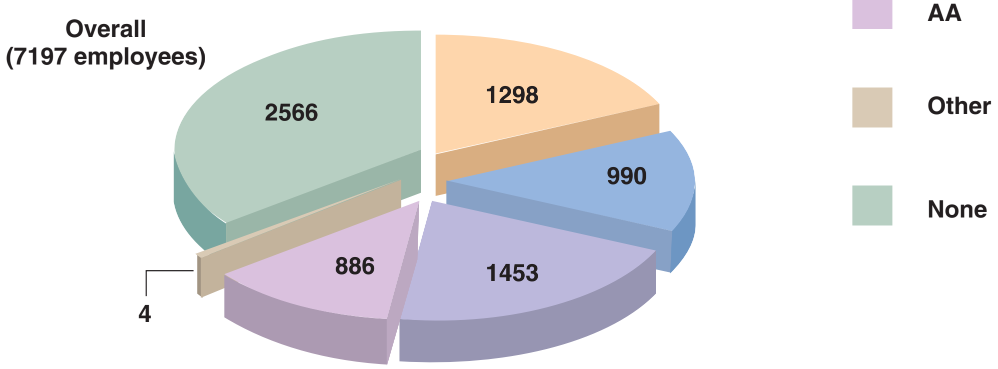



## Laboratory degree distribution
(as of 12/31/02)



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